CONDENSED ENCYCLOPEDIA OF ENGINEERING

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A COMPACT WORK OF REFERENCE CONTAINING THE MOST ESSENTIAL FACTS ABOUT 4150 SUBJECTS IN MECHANICS AND ENGINEERING, INCLUDING ESTABLISHED RESULTS AND DATA OF IMPORTANCE TO DESIGNERS AND BUILDERS OF MECHANICAL AND ELECTRICAL APPARATUS

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THE PURPOSE OF THIS BOOK

This Condensed Encyclopedia of Engineering supplies, in compact form, the essential facts about a very large variety of important subjects related to engineering and manufacturing practice. It is intended not only for engineers, designers, and mechanics in general, but for managers, purchasing agents, patent attorneys, inventors, and others directly or indirectly connected with mechanical work, and is especially for those who want to get the main facts quickly. By omitting minor details and giving only the summaries covering conclusions, results, usable data, and underlying principles, it has been possible to deal in a single volume with thousands of subjects.

This handbook type of encyclopedia covers in condensed form the same general field as MACHINERY'S large seven-volume Encyclopedia — but it is for those preferring a more compact work expressly arranged for reference use. While this handbook-encyclopedia consists largely of condensed items and treatises, it includes many definitions of words and expressions used in the engineering and machine-building industries, including numerous shop and trade terms. Very common words or expressions generally understood and found in standard dictionaries have been excluded, as they would serve no useful purpose and occupy space which has been used to better advantage. Definitions are followed with the more important facts about a subject whenever such additional information is likely to be of practical use; hence this work is of much greater practical value than a mechanical dictionary restricted to mere definitions.

The Condensed Encyclopedia of Engineering can be used either as a reference work or as a means of obtaining within a brief period, a broad fund of useful knowledge. It may also be used very effectively in conjunction with MACHINERY'S Handbook, as the explanatory matter, definitions and miscellaneous information cover a wide range of standard and special subjects which supplement the engineering tables and data in the handbook. Suggestions or criticisms for the improvement of future editions of this book will be much appreciated.

FRANKLIN D. JONES, EDITOR.

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ABRASIVE. An abrasive, such as is used in making grinding wheels or abrasive cloth and paper, may either be natural or artificial. The natural abrasives, such as emery and corundum, have been replaced largely by artificial abrasives, of which there are two general classes. One class is known as silicon carbide abrasives and the other as aluminous abrasives. The raw materials used in making the silicon carbide abrasives are pure glass or silica sand and carbon supplied by coke of various grades. The aluminous abrasives are made from bauxite, which is mined in the southern part of the United States and in various other parts of the world.

The two general classes of abrasives mentioned are sold under trade names. The silicon carbide group includes such abrasives as carbolite, carbolon, carborundum, carbosolite, carbowalt, corex, crystolon, electrolon, gresolite, maxf carbo, and sterbon. In the aluminous group are such abrasives as adamite, alowalt, aloxite, alundum, borolon, calcinite, carbo-alumina, combin, corem, corolox, corowalt, dessus, diamantite, electrit, jeddite, lyonite, maxf M, maxf sapphite, oxaluma, rebite, rex, rexite, and sterlith. For information about the applications of the silicon carbide and aluminous abrasives see Grinding Wheel Selection.

ABRASIVE GRADING. The modern method of grading abrasives is by the use of screens or sieves having openings between wires of certain standard dimensions. These screens conform to a table in which the wire diameters and the tolerances for both wire diameters and openings are given. Formerly, the number of screen meshes per lineal inch was used to indicate the screen size, but it is evident that accurate screening must take into account possible variations in wire sizes.

The screens used in testing commercial abrasives are made according to specifications of the Bureau of Standards. The openings in successive screen sizes vary by the fourth root of 2, so that every screen is 1.189 times the size of the preceding one. The standard screen or sieve number differs slightly in most cases from the actual number of meshes per inch. For example, a No. 10 screen has 9.2 meshes per inch. A No. 100 screen has 101 meshes per inch, there being slight variations throughout the series with a few exceptions.

The standard screen numbers are applied to loose abrasives used in polishing and also to abrasives used in grinding wheel manufacture. The arbitrary numbers or symbols, such as varying numbers of ciphers, for indicating the grading of certain classes of abrasive paper and cloth have been largely superseded by the standard screen numbers. This standard system of grading abrasives has been adopted by the Grinding Wheel Manufacturers' Association of United States and Canada.

ABSCISSA. In analytical geometry, points are located by designating their distance from two given intersecting lines or axes. In Fig. 1, XX

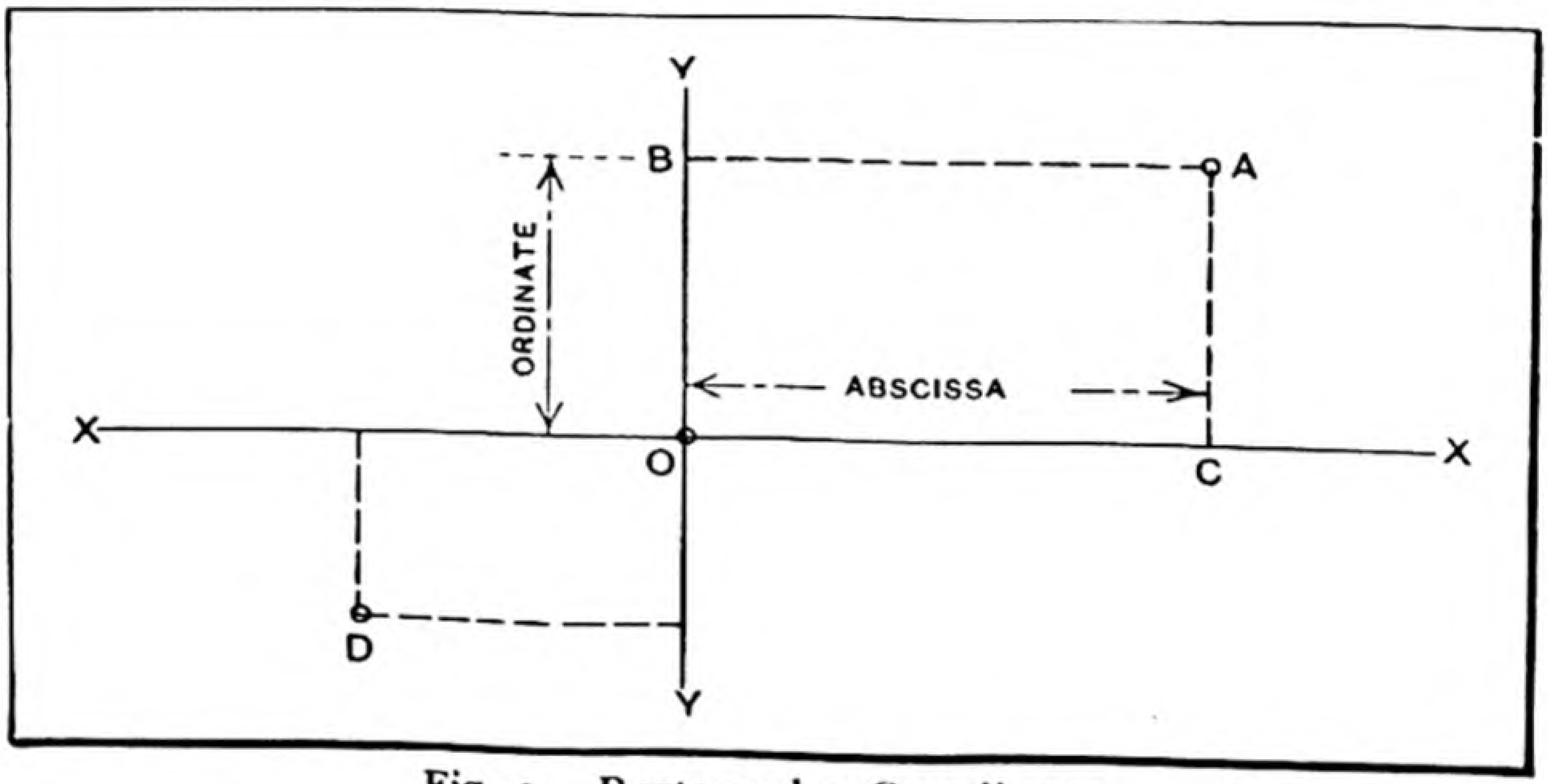


Fig. 1. Rectangular Coordinates

and YY are the axes, generally known as *coordinate* axes. These intersect at point O, called the *origin*. The distances measured parallel to axis XX are known as *abscissas;* those measured parallel to axis YY are called

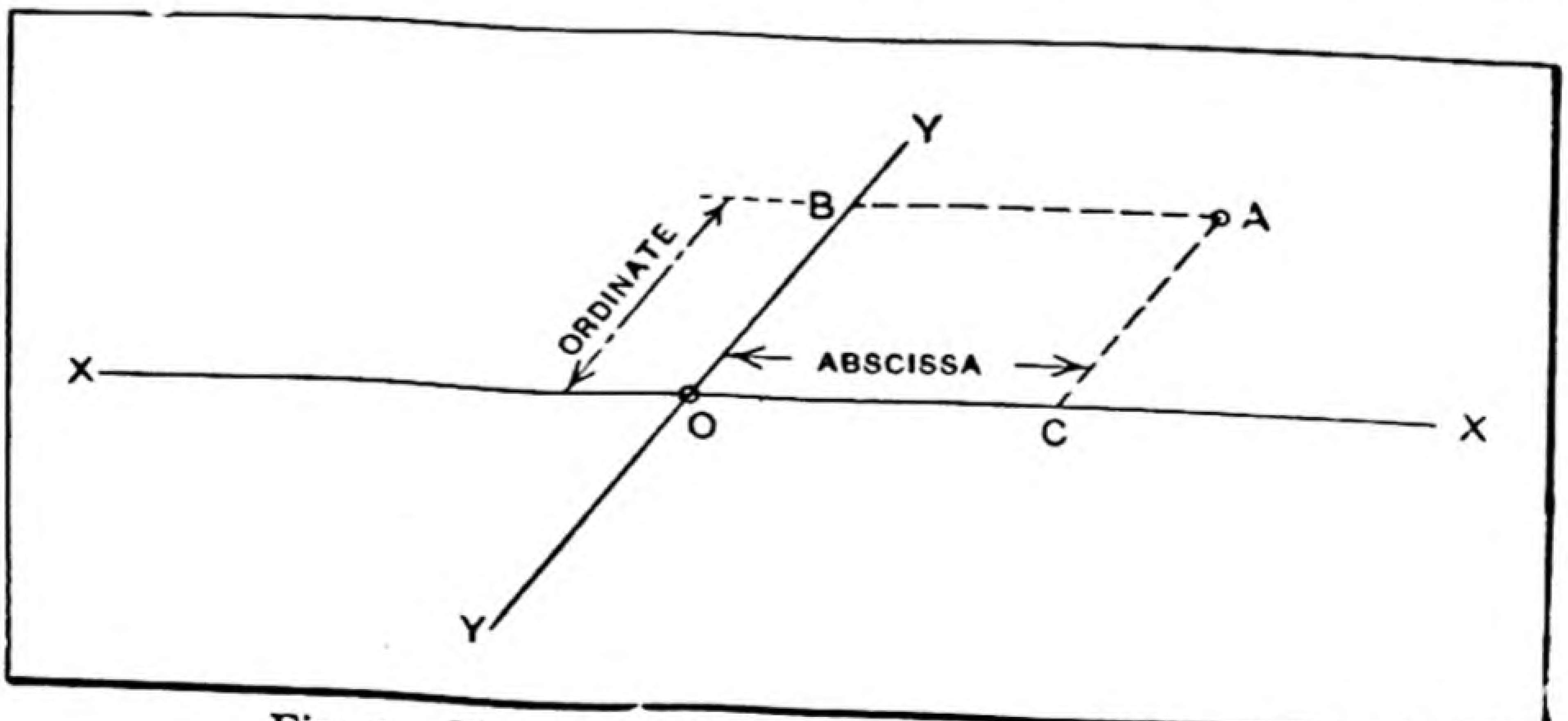


Fig. 2. Measurement of Abscissas and Ordinates

ordinates. In mathematical expressions, the abscissa of a point is generally designated by the letter x and the ordinate by y. The two axes are generally

at right angles to each other, in which case they are called *rectangular coordinates.* If the axes are not at right angles to each other, the abscissas and ordinates are measured along lines *parallel* to the axes, and not along lines at right angles to the axes. This is indicated in Fig. 2. The location of the axes is assumed to be known; the location of any point in the same plane, as A, can then be given in terms of its distance from the two axes. For example, if AC equals 2 inches, and AB, 3 inches, the location of point A is definitely given with relation to the axes and the origin.

Abscissas measured to the right of axis $Y\,Y$ are *positive* in value, those measured to the left are *negative.* Ordinates measured above the axis $X\,X$ are positive, those measured below, negative. Hence, both the abscissa and ordinate of point A, Fig. 1, are positive, but of point D, both are negative.

ABSOLUTE AND GAGE PRESSURE. The pressure of air, gases, or fluids is generally measured either in absolute pressure or in gage pressure. When measured in absolute pressure, the pressure of the atmosphere is included; the gage pressure is the pressure above that of the atmosphere. The pressure of air at sea level is 14.7 pounds per square inch. Gage pressure may be determined by simply subtracting 14.7 from the absolute pressure.

The steam pressure gage of a boiler measures gage pressure. All pressures used in compressed air computations should be measured from an absolute vacuum, which, for ordinary conditions, is 14.7 pounds per square inch below that of atmospheric or *gage* pressure. In like manner, the *absolute temperature* should be used, which for work of this kind may be assumed as equal to the degrees Fahrenheit plus 460.

ABSOLUTE CONSTANT. See Constants in Mathematics.

ABSOLUTE EFFICIENCY. See Mechanical Efficiency.

ABSOLUTE SYSTEM OF MEASUREMENT. The system of measurement almost universally used in scientific work is based upon the length and weight units of the metric system, with the second as the time unit. The system is known as the C.G.S. (centimeter-gram-second) system or the "absolute system of measurement." As indicated by the letters C.G.S., the centimeter is the unit of length; the gram, the unit of mass (or weight); and the second, the unit of time. From these basic units are derived a number of other units for measuring velocity, force, work, power, etc. These are:

Unit of velocity = 1 centimeter in one second.

Acceleration due to gravity (at Paris) = 981 centimeters in one second.

Unit of force = 1 dyne = $\frac{1}{981}$ gram.

Unit of work = 1 erg = 1 dyne-centimeter.

Unit of power = 1 watt = 10,000,000 ergs per second.

The C.G.S. system of power measurements is used exclusively for electrical machines and apparatus on account of the simple relationship which exists between the various units. The unit of work, erg, is so small that in practical work the *joule* is usually employed instead. One joule equals 10,000,000 ergs.

ABSOLUTE TEMPERATURE. A point has been determined on the thermometer scale which is called the *absolute zero*, and beyond which a further decrease in temperature is inconceivable. This point is located at −273 degrees Centigrade, or −459.2 degrees Fahrenheit. A temperature reckoned from this point, instead of from the zero on the ordinary thermometers, is called *absolute temperature*. To find the absolute temperature, when the temperature in degrees F. is known, add 459.2 to the number of degrees F. For example, find the absolute temperature of the freezing point of water (32 degrees F.). According to the rule given, 459.2 + 32 = 491.2 absolute temperature Fahrenheit.

ABSOLUTE VELOCITY. The absolute velocity of a moving body, is its velocity with reference to some object which is considered completely at rest. In practical mechanics, the earth is assumed to be stationary, so that the velocity of any moving body, as for example, a moving train with relation to the rails, would be absolute velocity. The term "absolute velocity" is used to distinguish it from *relative velocity*, which is the rate of motion of a body with relation to another moving body. See also Velocity.

ABSORPTIOMETER. The absorptiometer is an instrument invented by Prof. Bunsen, with which it is possible to determine the amount of gas absorbed by a unit volume of a liquid. In its simplest form, this instrument consists of a graduated tube in which a certain quantity of the gas and liquid is agitated over mercury. The amount of gas absorbed by the liquid is measured by the graduations on the scale; the height to which the mercury will rise in pressing up the liquid in the tube, when the gas has been partly absorbed, indicates the degree of absorption.

ABSORPTION DYNAMOMETERS. See Dynamometers.

ABSORPTION OF GASES. Many liquids have a capacity for taking up or absorbing a certain quantity of gases. The quantity thus absorbed varies with the nature of the liquid and the gas. Many gases, for example, are readily absorbed by water; thus, water will absorb its own volume of carbonic-acid gas, over two times its volume of chlorine, and 430 times its volume of ammonia, but not more than 5 per cent of its volume of oxygen. The weight of gas that a given volume of liquid will absorb is proportionate to the pressure, but as the volume of a given mass of gas is proportionately less as the pressure increases, the volume which a given amount of liquid will

absorb at a certain temperature is constant, whatever the pressure. Water, as mentioned, absorbs its own volume of carbonic-acid gas at atmospheric pressure. If the pressure is doubled on both the gas and water, it will still absorb its own volume of the gas under the higher pressure, but, in that case, the density of the gas is doubled and, consequently, double the weight of the gas is dissolved. The quantity of gas absorbed increases as the temperature is lowered. One of the most important instances of the absorption of gases by liquids is met with in the absorption of acetylene by acetone; the latter liquid absorbs, at 60 degrees F. and 180 pounds pressure per square inch, 300 volumes of acetylene gas. This property of acetone makes it possible to safely store and transport acetylene gas in steel cylinders or containers.

ABSORPTION SYSTEM OF REFRIGERATION. A method of refrigeration making use of the following equipment: a generator or still in which ammonia gas is driven off from a solution of ammonia in water through the agency of heat; a condenser in which the ammonia gas is condensed; a brine coil in which the ammonia absorbs heat by vaporization from the brine; an absorber in which the ammonia from the brine coil is absorbed by a weak solution of ammonia in water; a pump which returns the liquid from the absorber to the generator; an analyzer which forms the upper part of the generator and receives the solution from the pump; a rectifier placed between the analyzer and condenser; an exchanger placed between the generator and the absorber; and an expansion valve placed between the condenser and the brine coil.

ACALORIN. A paint of German origin, the purpose of which is to intercept the heat rays of the sun, thus rendering rooms of a building protected by this paint from 10 to 25 degrees cooler than they would otherwise be. The paint is suitable for use on roofs, windows, and walls exposed to the sun; it is light blue in color and does not appreciably decrease the amount of light admitted through windows covered by it.

ACCELERATION. The rate of change in the velocity of a moving body is called *acceleration;* hence, the acceleration is the increase in velocity of a body during a very short interval of time, usually one second. When the motion is decreasing instead of increasing, it is called *retarded motion*, and the rate at which the motion is retarded is frequently called the *de-acceleration* or the *deceleration*. The acceleration is said to be uniform if the body gains equal increments of velocity in a given direction in equal successive units of time. A constant force produces a uniform acceleration. Gravity, for example, acting upon a falling body, causes it to fall with a uniformly accelerated motion, providing the effect of the atmospheric resistance is not considered. The acceleration due to gravity varies from 32.09 at the equator to 32.255 at the poles. The value at sea level and

for a latitude of about 41 degrees is 32.16, which is the value commonly used.

ACCUMULATOR. An accumulator is a hydraulic machine for the accumulation or storage of energy to be expended intermittently for power purposes, as in riveters, and hydraulic machinery, such as hydraulic elevators and presses. One type consists principally of a vertical cylinder fitted with a plunger, to the upper end of which are secured weights sufficient to produce the required pressure. Water is forced into the cylinder by a pump, raising the plunger and the weights. The plunger and weight react upon the water, when the operating valve at the machine is opened, and cause the pressure to be transmitted to the machinery to be operated. The type of hydraulic accumulator in which the plunger is weighted down is known as the "direct" form. Another type in which the cylinder, fitting over the plunger from above, supports the weights, is known as the "inverted" type.

In electricity, a *storage battery* is called an accumulator. The term seldom has this meaning in the United States.

ACETONE. Acetone is a liquid obtained by the destructive distillation of acetates and produced, on a large scale, from the watery liquid obtained in the dry distillation of wood. It has the property of absorbing many times its volume of acetylene gas and is, therefore, used to a great extent in the oxy-acetylene welding and metal-cutting industry. The successful use of acetylene gas depends, to a great degree, upon the fact that it can be absorbed by acetone, and thus used without exposing those in the vicinity of the acetylene container to the dangers of a possible explosion from the gas. The method was invented by French engineers in 1896. One volume of acetone at 60 degrees F., under atmospheric pressure, will absorb 25 volumes of acetylene gas. At a pressure of 180 pounds per square inch, 300 volumes of the gas will be absorbed. Hence, by this method, an enormous quantity of acetylene gas can be stored and transported safely under comparatively low pressure, in cylinders of moderate size. When the pressure is relieved, the acetylene gas escapes gradually. The acetone can be used over and over again for the storage of acetylene gas, the loss in acetone being only about one pound for each 1000 cubic feet of acetylene. The porous substance used in the cylinders is a fine fibre or asbestos bound together with silicate of soda, melted in cakes to fill the interior of the cylinders for which they are intended. This material is porous and admits the acetone into the minute cavities.

ACETYLENE. Acetylene is a gaseous compound of carbon and hydrogen (chemical formula C_2H_2). It is a colorless gas having a specific gravity of 0.92 (air = 1). It is produced by the action of water upon calcium carbide.

Acetylene gas cannot be stored in a compressed state directly in cylinders, because of the danger from explosion, but acetylene is soluble in a number of liquids, and, by dissolving in these liquids, acetylene may be stored with safety. Acetone is the liquid generally used for this purpose. Acetylene gas is of the greatest industrial importance in connection with autogenous welding and cutting of metals, where the great heat of combustion, when using it in conjunction with oxygen, is made use of. The oxy-acetylene flame is far hotter than the oxy-hydrogen flame, and the fact that it is reducing in character is of great advantage in autogenous welding.

Acetylene was discovered in 1836, but until 1892 its production was merely a laboratory experiment. In that year calcium carbide was accidentally manufactured in an electric furnace at the works of the Willson Aluminum Co., in North Carolina. It was considered of no value and was thrown into the river. It was then accidentally discovered that the gas arising from it when thrown into water, would ignite, and a further investigation proved that this was acetylene. Its commercial exploitation began shortly afterward in its use for isolated lighting plants.

ACETYLENE GENERATOR. A device used for producing acetylene gas, there being two main classes: (1) generators in which water is brought into contact with calcium carbide, the carbide being in excess; and (2) generators in which carbide is dropped into water, the amount of water being in excess.

ACETYLENE SLUDGE. The residue or sludge from the carbide in acetylene generators makes a very serviceable whitewash for the workshop, particularly the pits in railroad shops where regular whitewash does not readily adhere to the walls. The sludge from the generating plant may be mixed with water, and is usually spread on the walls by air pressure, the same as ordinary whitewash. It has also been found serviceable as building mortar, and has some value as a fertilizer.

ACHESON PROCESS. The method of making silicon carbide — the abrasive used in carborundum grinding wheels — by the electric process has, after the inventor, Dr. Acheson, been named the "Acheson process." Carborundum is produced from quartz and carbon, these substances being heated in an electric resistance furnace. The furnace has a granular carbon core around which a charge consisting of quartz, carbon, sawdust, and sodium chloride is packed. Carborundum is formed at a temperature of 1840 degrees C. (about 3340 degrees F.), and decomposes if it is heated above 2240 degrees C. (about 4060 degrees F.). Carborundum is used both as an abrasive, and in furnace linings, and has been employed as a substitute for ferrosilicon in the manufacture of steel.

ACID. In chemistry, an acid is a compound containing hydrogen in which the hydrogen may be replaced by a metal, or a group of elements equivalent to a metal, to form a salt. An acid is also defined as a compound that will unite with a base to form a salt and water. Most acids are soluble in water, have a sour taste, turn vegetable blue into red, decompose most carbonates displacing the carbonic acid (carbon dioxide) with effervescence; they have also the power of destroying more or less completely the characteristic properties of alkalies. The acids in common use in the industries are hydrochloric, nitric, sulphuric, and hydrofluoric.

ACID BESSEMER PROCESS. See Bessemer Process.

ACID FIREBRICK. A firebrick in which silica predominates and which is generally known as "silica brick."

ACID, HYDROCHLORIC. See Hydrochloric Acid.

ACID, HYDROFLUORIC. See Hydrofluoric Acid.

ACID NUMBER OF OIL. Free fatty acids represent the amount of free organic acid present in the oil, and this should not be confused with mineral acid, as free fatty acids are a normal constituent of the so-called "fixed" or fatty oils. Free fatty acids are determined by titrating in an alcoholic solution with a standard potash solution. The "acid number" is another method of expressing free fatty acids and is the number of milligrams of caustic potash required to neutralize one gram of the fat or oil.

ACID, PICRIC. See Picric Acid.

ACID-PROOF CEMENT. A cement composed of boiled linseed oil and fireclay resists most acid vapors. A tough and elastic cement is made from 1 part of crude rubber, 4 parts of boiled linseed oil, and 6 parts of fireclay. The rubber is dissolved in carbon disulphide, until a mixture of the consistency of molasses is obtained, and is then mixed with the oil. Asphalt compositions, and compositions of melted sulphur with fillers of stone powder, Portland cement, or sand may also be used as acid-proof cements.

ACID-PROOF TANK LINING. A lining for protecting tanks from the corroding effect of acids is made from a mixture consisting of 75 parts (by weight) of pitch; 9 parts of plaster-of-paris; 9 parts of ochre; 15 parts of beeswax; and 3 parts of litharge. The tanks are covered on the inside with a thick coat of this mixture.

ACID-RESISTING ALLOYS. An alloy which has resisted, when subjected to tests, the action of 25 per cent nitric acid for twenty-four hours without a measurable loss in weight, consists approximately of 6.5 per cent copper; 1.0 per cent of manganese; 1.0 per cent of silicon; 2.25 per cent of

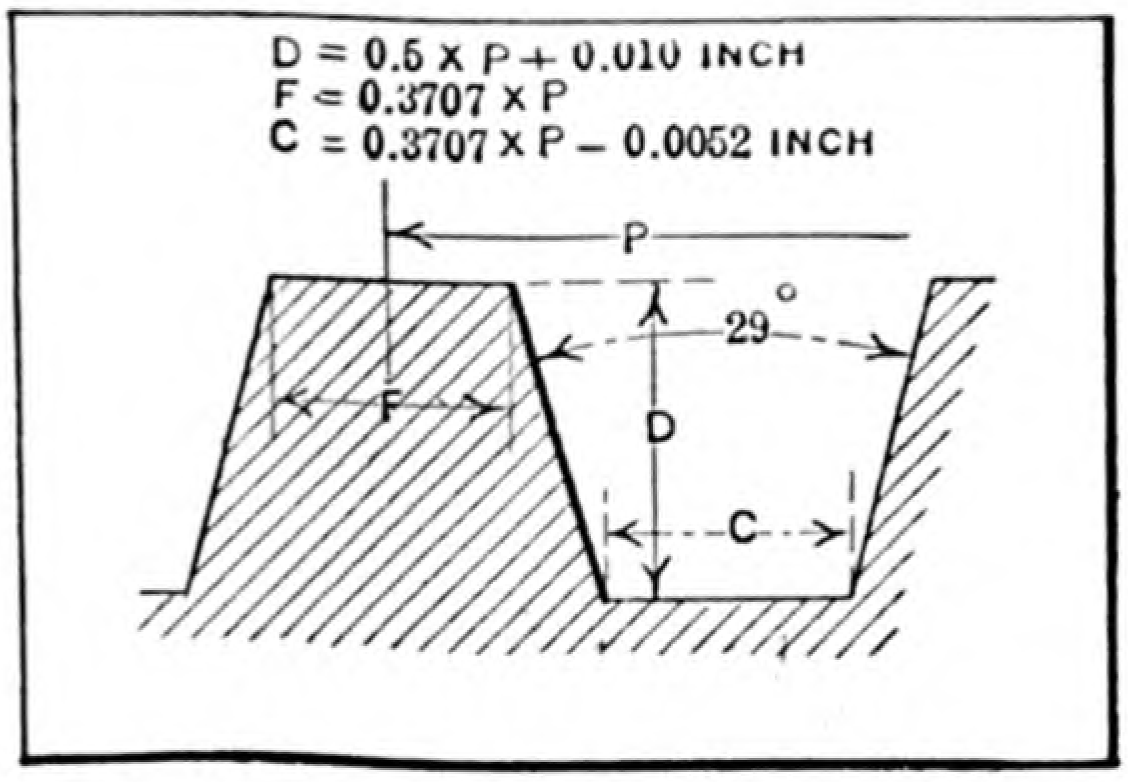
tungsten; 1.1 per cent of aluminum; 0.8 per cent of iron; 4.75 per cent of molybdenum; 21.1 per cent of chromium, and 61.5 per cent of nickel. The melting point of the alloy is approximately 2370 degrees F. When thoroughly liquid, the alloy pours readily and fills the mold perfectly, but the freezing point is so quickly reached that feeding of the casting from risers to make up for shrinkage is practically impossible, while the shrinkage is so excessive that cracks and hollow spots are very difficult to avoid. The material can be machined in a lathe about the same as tool steel. The tensile strength of the cast metal is about 50,000 pounds per square inch. Another acid-resisting alloy which is similiar to the preceding one contains: Nickel, 66.6 per cent; chromium, 18 per cent; copper, 8.5 per cent; tungsten, 3.3 per cent; aluminum, 2 per cent; manganese, 1 per cent; titanium, 0.2 per cent; boron, 0.2 per cent; and lithium, 0.2 per cent. This alloy is difficult to cast, but can be forged and drawn into wire. See also Illium.

ACID-RESISTING IRON. See Duriron.

ACID SALT. In chemistry, an acid salt is a salt formed when only part of the hydrogen in the acid is replaced by the base.

ACIDS, ETCHING. See Etching Acids.

ACME THREAD. The Acme thread (see illustration) is extensively used in preference to the square thread, especially for lead-screws and similar parts. The Acme form is stronger than the square thread, and it may be cut with a die more readily than a square thread. When an Acme thread is engaged by a sectional nut like the half-nut of a lathe apron, engagement or disengagement is more readily effected than with a square thread; an adjustable split nut may also be used in connection with an Acme screw thread to compensate for wear and to eliminate back-lash or lost motion. The depth of an Acme thread is made equal to one-half the pitch plus 0.010 inch to provide clearance between the top of the screw thread and the bottom of the thread groove in the nut. The included angle between the sides of the thread is 29 degrees.



Acme Thread

ACUTE ANGLE. See Angle.

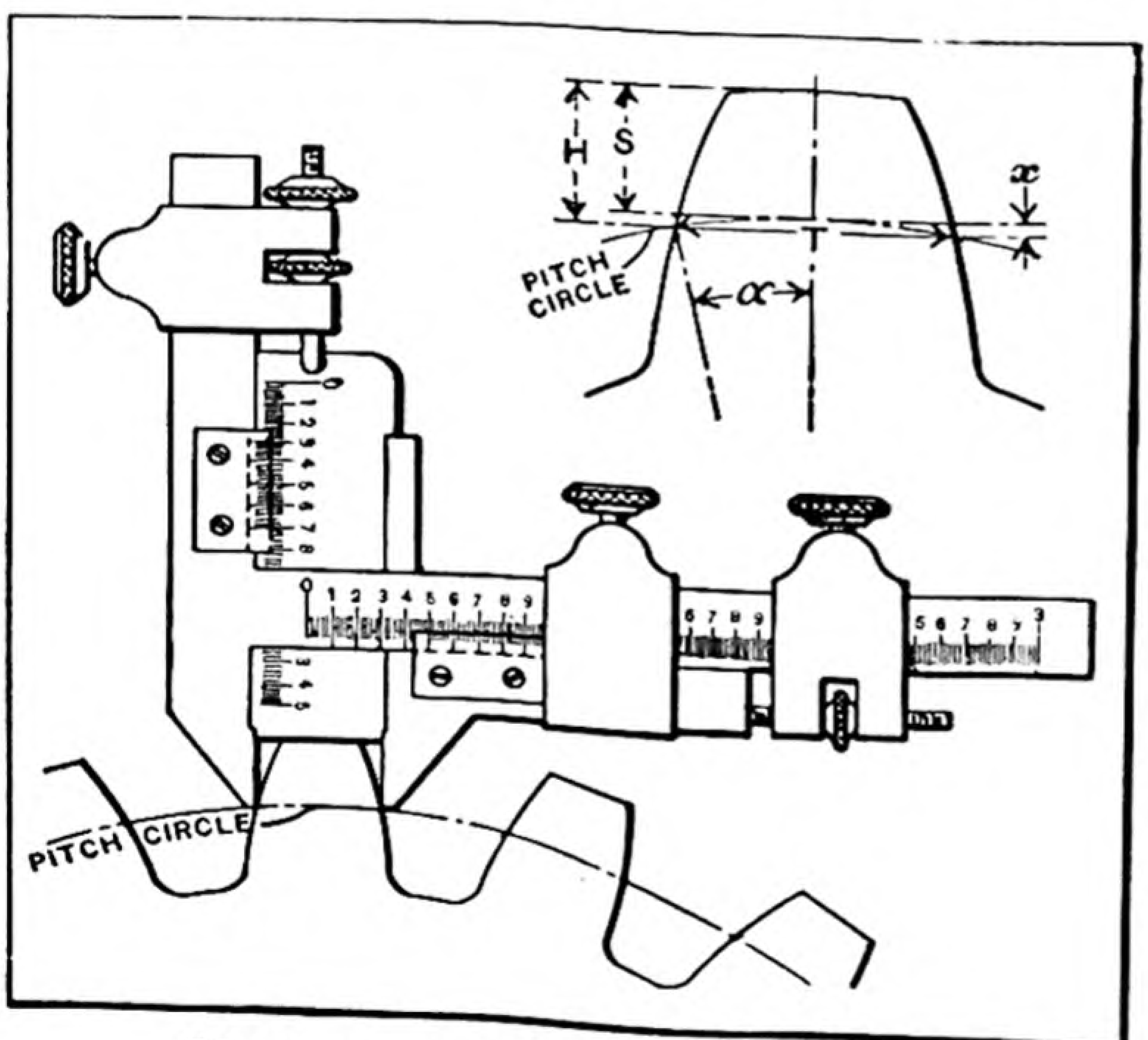
ACYCLIC MACHINES. Acyclic machines, sometimes also called "homo-polar" or "uni-polar," are direct-current machines in which the

voltage generated in the active conductors maintains the same direction with respect to those conductors. The machines will operate equally well as motors or generators and have the same inherent features, but are not very extensively used. The current delivered by the machine is not a commutated alternating current, but is direct.

ADAMITE. Adamite is a trade name of an artificial abrasive the chief constituent of which is aluminum oxide, which is mixed with certain ingredients in order to remove the impurities and is fused at a high temperature in the electric furnace. Adamite is used in wheels for grinding materials of high tensile strength, such as soft and hardened steel.

ADAMANTINE BORON. A crystalline form of the chemical element *boron*. It has a luster and hardness only slightly inferior to that of the diamond.

ADDENDUM. The addendum of a gear tooth is the distance (S in illustration) from the pitch circle to the top of the tooth. In standard diametral pitch gearing, the addendum is always equal to 1 divided by the diametral pitch. The *corrected addendum* is the perpendicular distance measured from the chord across the tooth at the pitch circle to the top of the tooth, as shown at H in the illustration. This distance is used when measuring the thickness of gear teeth at the pitch line by gear-tooth calipers, as indicated. When a gear tooth is measured in this way, it is the chordal thickness T that is obtained, instead of the thickness along the pitch circle.



Measurement of Gear Tooth Thickness

If α = one-half of the angle subtended from the center of the gear by one gear tooth (see illustration); N = number of teeth in gear; T = chordal thickness of tooth at pitch line; and R = pitch radius of gear; then:

$$\alpha = 90° \div N; \qquad T = 2\,R \times \sin \alpha.$$

The height x of the arc equals 1 minus the cosine of angle α, multiplied by the pitch radius of the gear, or, expressed as a formula, $x = R(1 - \cos \alpha)$. The vertical scale of the caliper is set to dimension H or x + addendum S.

ADHESION AND FRICTION. Friction should not be confused with "adhesion," which not only resists the motion of one body upon another, but tends to hold the two together so that they cannot be separated. Adhesion is independent of the pressure between the bodies, while friction increases with the pressure. Moreover, the smoother the rubbing surfaces the greater is the adhesion but the less is the friction; two perfectly smooth surfaces, if such were possible, would be frictionless, while the adhesion between them would be very great, as in the case of precision gage-blocks. Lubricants increase the adhesion and diminish the friction. When the pressure between two bodies is small, the adhesion forms a considerable part of the resistance, and, as the pressure increases, it becomes proportionately less, since adhesion does not increase with the pressure. At ordinary pressures, the effect of adhesion can generally be neglected, and the whole resistance considered as friction. The coefficient of friction of solid rubber tires on cement and vitrified brick roads is about 0.6, while that of pneumatic tires under similar conditions is 0.5. The coefficient of adhesion is greater than that of friction, and incidentally this partly explains why an automobile stops more rapidly when the wheels are kept moving than when they are locked; hence the increased danger when a car skids if the rear wheels are locked by the brakes.

ADHESION, GAGE-BLOCK. See Gage-block Adhesion.

ADIABATIC CURVE. A curve used in a diagram to show the condition under which a gas, such as air, is compressed or expanded in adiabatic compression.

ADIABATIC EXPANSION AND COMPRESSION. Adiabatic expansion means that heat is neither added nor taken away during the expansion of air or gases; hence such expansion is accompanied by a reduction in temperature. Inversely adiabatic *compression* is accompanied by a rise in temperature. The pressure during adiabatic expansion falls faster than with isothermal expansion and rises faster for adiabatic compression than for isothermal compression. See also Isothermal Expansion and Compression.

ADIT. Adit is an electric insulating material made from impregnated papier-maché covered with an insulating compound. It can be molded to any form required, and in different grades withstands heat from 140 degrees F. up to 250 degrees F. It is a non-combustible insulation. With a thickness of about $\frac{3}{32}$ inch, a voltage of 1000 is required to puncture a sheet of

adit. The voltages required to puncture thicknesses of $\frac{5}{32}$ and $\frac{7}{32}$ inch are 3000 and 4000, respectively.

ADMIRALTY METAL. A name used for a number of alloys having the property of resisting the action of sea water, and used for parts of engines and machinery on board ships. One alloy consists of 87 per cent of copper, 5 per cent of zinc, and 8 per cent of tin. Another alloy, used for surface condenser tubes exposed to sea water, is composed of 70 per cent of copper, 29 per cent of zinc, and 1 per cent of tin.

AEROMETER. Instruments for weighing air or for ascertaining the density of air, gases, or fluids are generally known as *aerometers.* The barometric aerometer is an instrument which consists of a vertical U-tube with open ends, mounted upon a stand in such a manner that it can be used for measuring the relative specific gravities of liquids. The method in which it is used is as follows: Water is poured into one branch of the tube, and the oil or liquid, the specific gravity of which is to be measured, is poured into the other. The vertical parts of the tube are provided with graduations. If it is found, for example, that 9 inches of water balances 10 inches of oil, then the relative specific gravities are as 10 to 9 or the specific gravity of the oil is 0.9.

AFTERBLOW. That part of the basic Bessemer process during which the phosphorus is oxidized and removed.

AGING. A term used to express the increase in hysteresis loss in the core laminations of electrical machines. See Hysteresis.

AGOMETER. The agometer is a form of rheostat of which the mercury agometer is the most common. This instrument is used for measuring electrical resistances, or for varying the resistance of a circuit by means of a mercury column, the length of which may be adjusted as required.

AGRICULTURAL BOLT. A bolt used in farming machinery, the body of which is provided with a number of helical grooves formed by rolling.

AICH METAL. Aich metal is an alloy of about 38 per cent zinc, 60 per cent copper, and 2 per cent iron. Sometimes the iron percentage is only 1.5 per cent. It is malleable at a red heat and can be hammered, rolled, or drawn into fine wire. The metal has been used as a material for cannons. The tensile strength is about 50,000 pounds per square inch; the addition of a small percentage of iron increases the strength perceptibly. At temperatures of from 200 to 1000 degrees F., Aich metal is about 50 per cent stronger than brass of about the same composition, but without the iron. The strength of Aich metal at 200 degrees F. is about 45,000 pounds per square inch; at 500 degrees F., 30,000 pounds per square inch; and at 900 degrees

F., 10,000 pounds per square inch. There are a number of alloys of a similar composition, but the principal feature of them all is the addition of iron to a copper-zinc alloy.

AIR. Air is a mechanical mixture composed of 78 per cent, by volume, of nitrogen, 21 per cent of oxygen, and 1 per cent of argon. The weight of pure air at 32 degrees F., and an atmospheric pressure of 29.92 inches of mercury or 14.70 pounds per square inch, is 0.08073 pound per cubic foot. The volume of a pound of air at the same temperature and pressure is 12.387 cubic feet. The weight of air, in pounds per cubic foot, at any other temperature or pressure may be determined by first multiplying the barometer reading (atmospheric pressure in inches of mercury) by 1.325 and then dividing the product by the absolute temperature in degrees F. The absolute zero from which all temperatures must be derived in dealing with the weight and volume of gases, is assumed to be minus 459.2 degrees F. Hence, to obtain the absolute temperature, add to the temperature observed on a regular Fahrenheit thermometer the value 459.2. See also Aerometer.

AIR-BALANCED HOIST. See under Hoist.

AIR BRAKE ORIGIN. The modern automatic air brake which is employed universally on all railway trains, is the result of the pioneer work done by Mr. George Westinghouse, Jr., who began his experiments in 1869 and was granted his first patents in 1872. These patents have been followed by many others covering features for improving the air brake system. The automatic feature of this air brake system will be apparent when the general operating principle is understood. A continuous pipe line filled with compressed air extends from the locomotive throughout the train length, there being flexible connections between the cars consisting of rubber hose and special couplings. The engineer applies the brake by allowing air from the train line to escape, thus lowering the pressure, which causes valves on the various cars to shift, thus permitting air stored beneath each car to enter the brake cylinders and apply the brakes. If a train should pull apart (an accident liable to happen to a long heavily-loaded train), the breaking of the air or train line releases the pressure and all of the brakes are instantly and automatically applied.

AIR-BREAK SWITCHES. See Switches of Air-break Type.

AIR CHAMBER ON PUMP. Air chambers are used in connection with pump cylinders to reduce shock or "water-hammer," to permit higher speeds, and to give a more uniform discharge of water. The air chamber is attached near the discharge or outlet end. When the discharge occurs, the air in the chamber is compressed by the water, or other liquid, which is

forced up into it. The air chamber thus acts as a reservoir and forms a cushion. When the pump plunger is passing the end of its stroke, and the discharge greatly decreases or diminishes entirely, the compressed air in the chamber tends to keep the water moving through the discharge pipe, thus relieving the pump shocks by providing an elastic cushion and equalizing the rate of discharge so that the flow is more uniform.

Air chambers are particularly essential on pumps of the crank-driven type (especially if single-acting), because the speed of the plunger varies decidedly throughout the stroke. Many duplex direct-acting pumps do not have air chambers. The volume of the air chamber for ordinary boiler-feed and service pumps should be from two to three times the piston displacement for a single-cylinder pump, and from one to two times the displacement for a duplex type. If the piston speed is unusually high, as in the case of fire pumps, the air chamber should have a volume equal to about six times the displacement. Air chambers are sometimes applied to suction pipes, especially if the pipe is long, and the resistance to the flow of water is considerable. The pressure in the suction air chamber is always less than the atmospheric pressure when the pump is in operation, and for that reason it is sometimes called a " vacuum chamber." When the pump is running, the suction air chamber provides a cushion that gradually stops the movement of the column of water at the end of a stroke and assists in starting the water again on the next stroke.

AIR COMPRESSION. Theoretically, air may be compressed under two different conditions: *Adiabatic* expansion or compression of air takes place when air is expanded or compressed without transmission of heat to or from it, as for example, if air could be expanded or compressed in a cylinder made from a material that was absolutely non-conducting to heat. *Isothermal* expansion or compression of air takes place when air is expanded or compressed with an addition or transmission of sufficient heat to maintain a constant temperature. In actual practice, neither of these two theoretical extremes is obtainable. The work required to compress air isothermally is considerably less than the work required for compressing air adiabatically; the work required for air compression in actual practice is a medium between the work that would be required for either of the two theoretical conditions. See Isothermal Expansion and Compression.

AIR COMPRESSION, MULTI-STAGE. For the higher pressures air is compressed in *stages* and cooled between each stage. Single-stage compression is recommended for pressures up to about 50 or 60 pounds (absolute) per square inch; two-stage, for from 50 to 500 pounds; three-stage, for from 500 to 1000 pounds; and four-stage, for higher pressures. The principal reasons for multi-stage compression are: the saving in power by cooling

the air as it passes from one cylinder to the next; increased safety with regard to explosion; reduced strain on the compressor; better steam economy in the case of direct-acting steam-driven machines, owing to a better distribution of the load; more effective cylinder lubrication, due to lower air temperatures; greater volumetric efficiency, because the "clearance air" in the first cylinder, being at a lower pressure, does not expand so much on the return stroke, thus allowing an earlier admission of free air to the cylinder; and finally, the delivery of drier air to the receiver, owing to precipitation during the cooling process between the stages.

AIR COMPRESSION TERMS. Upon the recommendation of its technical committee, the Compressed Air Society has adopted the following definitions of certain compressed air terms, and the society recommends that the use of other expressions of efficiency be discontinued: The *displacement* of an air compressor is the volume displaced by the net area of the compressor piston. The *capacity* is the actual amount of air compressed and delivered, expressed in free air at intake temperature and at the pressure of dry air at the suction; it should be expressed in cubic feet per minute. *Volumetric efficiency* is the ratio of the capacity to the displacement of the compressor. *Compression efficiency* is the ratio of the work required to compress isothermally all the air delivered by an air compressor to the work actually done within the compressor cylinder, as shown by the indicator cards, and may be expressed as the product of the volumetric efficiency, the intake pressure, and the hyperbolic logarithm of the ratio of compression, all divided by the indicated mean effective pressure within the air cylinder or cylinders. *Mechanical efficiency* is the ratio of the air indicated horsepower to the steam indicated horsepower in the case of a steam-driven machine, and to the brake horsepower in the case of a power-driven machine. *Over-all efficiency* is the product of the compression efficiency and the mechanical efficiency.

AIR COMPRESSOR. An air compressor may be defined as a machine used for increasing the pressure of air or other gas from a lower to a higher stage by reducing the volume of air or gas or compressing it into a smaller space. Usually, in air-compressor practice, the lower or initial pressure is the atmospheric pressure, while the higher or terminal pressure is fixed by the requirements in each particular case, and may be anywhere from 10 to 30 pounds gage pressure per square inch, in blowing engine practice; from 80 to 100 pounds per square inch for rock drills, pneumatic tools, etc., up to from 1500 to 2000 pounds per square inch, or even higher, for special purposes. Compressors are generally provided with a piston working in a cylinder in which the compression takes place. To a certain extent, the compression of air in the cylinder of a compressor is the reverse of the ex-

pansion of steam in the cylinder of an engine. In the case of the former, work is expended upon the air, heat is generated, the pressure increased, and the volume reduced, while with steam, work is done, heat disappears, the pressure is reduced, and the volume increased.

Compressed Air Cooling Methods. — Various plans for taking away the heat during compression, such as injecting a spray of water into the cylinder, circulating cooling water through the piston and around the heads and cylinder barrel, etc., have been tried. The use of the cooling spray, or so-called "wet-compression," has long since been abandoned, as has also the plan of circulating water through the piston, for the disadvantages more than offset the possible gains. Cylinder heads and barrels are water-jacketed, not so much on account of the heat that can be taken from the air as to keep the cylinder cool enough for proper lubrication. The most effective means for taking away the heat of compression and reducing the amount of power required consists, however, in dividing the compression into two or more stages, depending upon the terminal pressure desired, and cooling the air as much as possible between stages by means of suitable cooling apparatus, the water-jacketing of the cylinders and heads being retained for the reason mentioned.

AIR COMPRESSOR CAPACITY. The capacity of a compressor is expressed in the cubic feet of *free air* which may be compressed to a given higher pressure in a unit of time. The term "free air' means air at atmospheric pressure, and is commonly taken at 60 degrees F. In designing an air compressor, it is generally required to work out the design for a given volume of air per minute at a given pressure. As compressors are usually rated in cubic feet of free air, it is often necessary to reduce the required volume of compressed air to its equivalent volume of free air. This may be done by dividing the volume of compressed air by the volume of 1 cubic foot of free air at the higher pressure.

Example: — A compressor is required to furnish 100 cubic feet of air per minute at a gage pressure of 80 pounds per square inch. What should be its rating in free air?

The volume of 1 cubic foot of free air at 80 pounds gage pressure is 0.267 cubic foot. Therefore, the equivalent free air required by the compressor is:

$$\frac{100}{0.267} = 375 \text{ cubic feet per minute.}$$

AIR COMPRESSOR RATING. Compressors are often rated upon piston displacement without regard to volumetric efficiency. The actual capacity under working conditions should be considered. The volumetric efficiency is the ratio of the actual volume of air taken into the cylinder

per stroke, to the piston displacement, and it varies with the amount of clearance and the terminal pressure. This efficiency is usually 90 per cent or over in compressors of approved design.

AIR ENGINES. There are two types of air engines. In the first type, the force of air expanded by heat in a cylinder causes a plunger to move, a representative engine of this type being the Rider-Ericsson hot-air pumping engine in which gas burners in a furnace below a vertical cylinder heat the air in the bottom of the cylinder, and, through the expansion, cause motion to be transmitted to a pumping piston from which the power may be transmitted. An ingenious mechanism is employed for transferring the air to the upper part of a cylinder where it is cooled off between strokes, and then for transferring it to the bottom of the cylinder to be again expanded. These engines in sizes of from 5 to 10 inches cylinder diameter, have a capacity for pumping from 150 to 1000 gallons of water per hour to a height of 50 feet.

In another type of air engine, air which has been compressed by a separate air compressor is used as the driving power. This type resembles a steam engine in its general features, having piston, cylinder, and valves of similar construction; the main difference being that compressed air is used as the expanding gas instead of steam. It is used for underground mining machinery, and was formerly applied to over-head traveling cranes, but the electric motor has now taken its place in this and many other applications.

AIR-HARDENING STEEL. The origin of modern high-speed steels may be traced back to a discovery by Robert F. Mushet in 1868. Experiments were being made with the use of manganese in the production of Bessemer steel, and at first there was no idea of improving tool steel. During these experiments it was discovered that one of the bars of steel had the property of hardening after being heated, without quenching or cooling it rapidly in the manner required to harden carbon steel. This steel, which was afterwards known as mushet or self-hardening steel, was found to contain tungsten. The newly discovered steel which possessed the property of hardening when allowed to cool slowly without quenching, proved to be harder than steel which was quenched in the usual way. This discovery of self-hardening or air-hardening steel, as it was also called, led to numerous experiments with different elements in various combinations and, as a result, an alloy steel was obtained which was superior to carbon steel for rapid machining operations. The discovery was made later that the quality of the steel could be improved if the cutting end were reheated and cooled in an air blast, instead of being allowed to cool by simply exposing the heated steel to the atmosphere. An analysis of a typical mushet self-hardening

steel showed the following composition: Tungsten, 5.441 per cent; chromium 0.398 per cent; carbon, 2.15 per cent; manganese, 1.578 per cent; silicon, 1.044 per cent.

AIR-LIFT PUMPING. With the air-lift method of pumping, compressed air is supplied to the bottom of a well and mixes with the water. By impregnating with air a column of water in a tube sunk into the water bed, the water is made lighter, so that the pressure of a column of air and water in the bottom of the tube is less per square inch than that of the water outside in the well or in the rock, gravel, or sand strata, so that an upward flow is obtained. The discharge pipe for the water and the pipe for leading the compressed air to the bottom of the well should be properly proportioned. They may be arranged in different ways.

AIR, MOISTURE IN COMPRESSED. See Compressed Air, Moisture in.

AIR OR VACUUM PUMP. An air pump or "vacuum pump" is used for exhausting or removing air or other gases from a closed vessel or container, thus producing a partial vacuum. Pumps of this class are extensively used in connection with steam engines and turbine condensers and other condensing apparatus. Air pumps for condenser service may be divided into two general classes known as "wet-air pumps" and "dry-air pumps," according to the conditions under which they operate. Air pumps of the *wet type* handle both air and the water of condensation, and those used with surface and jet condensers are practically the same, except in size, the volume of water handled being much less in the case of the former, as a separate pump is employed for the cooling water. Pumps of the *dry type* have come into use with the advent of the steam turbine, where a high vacuum is required, and are usually of the flywheel or the centrifugal type. They are connected with the condensing chamber in such a manner as to withdraw air only, the condensation being removed by a separate "hot-well" pump. This arrangement makes it possible to use valves designed especially for air, and thus maintain a considerably higher vacuum.

AIRPLANE OIL. This oil, as the name indicates, is especially intended for airplane engine lubrication. It must be made from pure highly refined petroleum products, be neutral in action and not show the presence of moisture, sulphonates, soap, rosin, or tarry constitutents indicating adulteration or lack of proper refinement.

AIRPLANE STRAND. A small 7- or 19-wire galvanized wire rope strand, made from crucible or plow steel wire, is known as airplane strand. It is used in airplane construction, and where a light-weight strand of great strength is required, and is made in diameters of from $\frac{1}{32}$ to $\frac{5}{32}$ inch, varying by 32ds. The $\frac{1}{32}$-inch size has 7 wires, while the $\frac{1}{16}$-inch and larger sizes

have 19 wires. The breaking strength in pounds of airplane strand is as follows: $\frac{1}{32}$-inch diameter, 125 pounds; $\frac{1}{16}$-inch diameter, 500 pounds; $\frac{3}{32}$-inch diameter, 1100 pounds; $\frac{1}{8}$-inch diameter, 2000 pounds; $\frac{5}{32}$-inch diameter, 3000 pounds.

AIR RECEIVER. Air receivers are used in connection with air compressors for the purpose of storing the air, so as to maintain a constant pressure and equalize the pulsations in the air as it comes from the compressor. The receiver also serves the purpose of collecting the water and grease held in suspension by the compressed air, and cools the air before it enters the transmission system. The air receiver plays an important part in obtaining the highest efficiency and most economical operation of a compressed-air installation. It is essential that the cubic capacity of the receiver be in the right proportion to the capacity of the compressor. The receiver should have a capacity of from 15 to 20 per cent of the free air capacity of the compressor (per minute), but, in large installations, the percentage is sometimes lower, and may vary down to about 10 per cent. To obtain good results, the receiver should be placed as near as possible to the compressor, and, in any case, not more than 50 feet distant.

AIR RESISTANCE. The resistance of air to the moving parts of machinery often is not considered. Yet still air may offer considerable resistance to parts having a certain form and moving at high speed, as is evidenced by the airplane which is lifted by the action of the propeller and planes against air resistance. Covering large rapidly revolving flywheels on both sides with light plates has a marked effect in reducing the air resistance of the spokes. This is rarely done, however, because of its first cost and appearance. In calculating the power necessary to move a vehicle or projectile, consideration must be given to the resistance of either still air or wind against which it is forced. The wind exerts pressure on sloping roofs and the sides of all buildings, towers, bridges, or any other structure, and they must be able to resist collapsing or overturning because of this force. Even wires have considerable wind resistance, which is increased greatly when they are covered with sleet. So-called "holes" in the air, met with by aviators, are probably due to variations in the velocity of the air movement at a certain point.

AIR RESISTANCE, RACING CAR. The amount of power required to overcome air resistance is a factor of importance in the design of racing cars. The horsepower required to overcome the air resistance may be determined approximately by the following rule. Multiply the cube of the velocity of the car in feet per second, by the projected area of the front of the car in square feet, and divide the product by 240,000. The projected area may be approximated by multiplying the width of the car body at the frame-line

adjacent to the front seat, by the distance from the center of the wheels to the highest point, which may either be the windshield, the seats, or the top. It will be noted that the foregoing rule merely gives the power required to overcome air resistance and not the actual driving power. In applying this rule it is assumed that the air is still, but if the car is driven against a wind of known velocity, this velocity should be added to the car velocity. Since air resistance is practically negligible for speeds below 15 miles per hour, it is unimportant in connection with low power cars and ordinary touring speeds.

AIR, SATURATED. Saturated air is air containing the maximum amount of water vapor possible at any particular temperature and barometric pressure. Atmospheric air usually contains a smaller amount of moisture (water vapor) than saturated air. The amount of moisture in atmospheric air relative to the amount of moisture in saturated air (humidity) is reported daily by the United States Weather Bureau, as well as the mean temperature and the barometric pressure. Variations in the amount of moisture modify the specific heat of air, and therefore the specific heat of dry air at a given temperature should be corrected for the actual humidity condition.

AJAX METAL. Ajax metal is a bearing metal that is composed of 77 per cent of copper, 11.5 per cent of tin, and 11.5 per cent of lead. Another bearing metal, known as *Ajax plastic bronze*, is characterized by a larger percentage of lead, the composition being 65 per cent of copper, 5 per cent of tin, and 30 per cent of lead. This latter metal is considerably cheaper than the Ajax metal itself, because the content of tin, which is the most expensive ingredient, is considerably decreased, and the content of lead, which is the cheapest of the metals used, is increased.

ALBION METAL. Albion metal is a combination of tin and lead made by covering lead with sheets of tin. The tin sheets are caused to adhere to the lead by passing the combination between rollers which exert considerable pressure upon the sheets.

ALCOHOL ANTI-FREEZING MIXTURES. See Anti-freezing Mixtures.

ALDEN BRAKE. The Alden brake or absorption dynamometer may be defined as a special form of water-cooled Prony brake. It is capable of absorbing large powers with remarkable steadiness and complete regulation, the characteristic feature being that even for large powers it is moderate in size. The dynamometer consists mainly of a smooth cast-iron disk keyed to a rotating shaft. This disk is enclosed in a cast-iron shell, formed of two disks with a ring at their circumference, which is free to revolve on the shaft. The interior of the cast-iron shell contains two copper disks, fitted to the shell in such a manner that between the sides of the shell and the copper

plates there is a water-tight space into which water, under pressure, is admitted, forcing the copper plates against the central disk. The chamber enclosing the central disk is filled with oil. To the outer shell is fixed an arm with weights, which resists the tendency of the shell to rotate with the shaft, this tendency being caused by the friction of the copper plates against the central disk.

ALGEBRA. That part of mathematics known as *algebra* may be defined as a generalized arithmetic. In arithmetic, the answer to a specific problem is always required. In algebra, a general solution is usually desired, which may be applied to all problems of a similar character. A quantity in mathematics is any number involved in a mathematical process, and, in algebra, letters are used instead of figures to represent numbers or quantities. The use of letters or symbols in place of the actual numbers simplifies the solution of mathematical problems and makes it possible to obtain the result more rapidly and accurately. The symbols used in algebra are mainly the letters of the alphabet. Ordinarily, the first letters of the alphabet are used to represent known quantities, and the last letters, unknown quantities. As a rule, small letters rather than capital letters are employed.

ALKALI. In chemistry, a base that will dissolve in water is known as an alkali. See Base.

ALKALINE BATTERY. A storage battery in which the active material of the positive plate is nickel hydrate and that of the negative plate is black oxide of iron, the electrolyte being a solution of potash in water.

ALKALINE QUENCHING BATHS. See Quenching Baths, Alkaline.

ALLIGATION. Alligation or "the rule of mixtures" are names applied to several rules or arithmetical processes for determining the relation between proportions and prices of the ingredients of a mixture and the cost of the mixture per unit of weight or volume. For example, if an alloy is composed of several metals varying in price, the price per pound of the alloy can be found as in the following example: An alloy is composed of 50 pounds of copper at 14 cents a pound, 10 pounds of tin at 29 cents a pound, 20 pounds of zinc at 5 cents a pound, and 5 pounds of lead at 4 cents a pound. What is the cost of the alloy per pound, no account being taken of the cost of mixing it? Multiply the number of pounds of each of the ingredients by its price per pound, add these products together, and divided the sum by the total weight of all the ingredients. The quotient is the price per pound of the alloy.

ALLOWANCE. The term "allowance," as applied to the fitting of machine parts, means a difference in dimensions prescribed in order to

secure classes of fits; in other words, allowance is the amount required either above or below a nominal size, so that a certain class of fit is obtained, as, for example, a running fit, a forced or pressed fit, etc. For instance, if the hole in a crank disk is 3 inches in diameter and the shaft is made 3.005 inches in diameter in order to secure a forced fit, the 0.005 inch would represent the *allowance* for that part. The terms "allowance" and "tolerance" are often — but incorrectly — used interchangeably; according to common usage "tolerance" is a difference in dimensions prescribed in order to allow unavoidable imperfections of workmanship.

ALLOY. An alloy is an intimate mixture of two or more metals melted together. Mixtures of this kind are generally mechanical in their nature, but are homogeneous; in some cases, they may form chemical compounds. As a rule, when two metals are melted together to form an alloy, the substance formed is, for all practical purposes, a new metal. Brass, bronze, and German silver are examples of well-known alloys.

ALLOYS, ACID-RESISTING. See Acid-resisting Alloys.

ALLOYS, DIE-CASTING. See Die-casting Alloys.

ALLOYS, NON-FERROUS. Alloys may be divided into ferrous and non-ferrous; the former contain iron as their chief component, while the latter do not. The most important of the ferrous alloys are the alloy steels. Of non-ferrous alloys, the bronzes and the brasses are the most important. *Bronze* is an alloy consisting of copper and tin in variable proportions, in which copper is the chief component. *Brass* is an alloy consisting of copper and zinc in variable proportions, with copper as the chief component. Besides bronze and brass, a classification of non-ferrous alloys that is used, but not universally adhered to, defines an alloy consisting of more than two metals with copper as the chief component as a *composition*. Thus a bronze composition is an alloy of copper and tin with one or more variable components, but in which tin is the chief minor component; a brass composition is an alloy of copper and zinc combined with one or more other components, but in which zinc is the chief minor ingredient. In general usage, brass and bronze compositions are frequently known simply as "brass" and "bronze."

ALLOY STEEL. A steel containing some metallic element other than iron and carbon, such as nickel, chromium, tungsten, vanadium, etc., is generally known as an "alloy" or "special" steel. These various metals, when added to steel in certain (generally small) percentages, add distinct properties; they especially increase the hardness and the toughness of the steel. Various alloy steels are treated separately under their respective headings.

ALMANDITE. See Garnet.

ALOWALT. Alowalt is a trade name for an artificial abrasive that is a product of the electric furnace. It is made from aluminum oxide.

ALOXITE. Aloxite is a trade name of an aluminous abrasive, and, like other artificial abrasives, is produced in the electric furnace. Bauxite is the raw material from which aloxite is made. In the process of manufacture, the bauxite, which in the natural state is in a granular mass and earthy form, is crushed and then calcined in order to remove all moisture prior to smelting. A certain amount of anthracite coal is then mixed with the calcined material, the coal being added in such proportions as to reduce the oxides of silicon and of iron in the bauxite during the smelting process, but to leave the alumina unreduced. During the smelting process, the reduced oxides of iron and silicon unite to form ferrosilicon, and the alumina is freed of practically all its impurities. As the ferrosilicon is heavier than the alumina, it sinks to the bottom of the furnace, where it is easily separated from the aloxite. After the smelting operation is completed, the furnace is allowed to cool, and then the ingot or " pig " is removed, crushed, and screened.

ALTERNATING CURRENT. An alternating electrical current is a current that alternates regularly in direction and, unless otherwise specified, the term " alternating current " refers to a periodic current with successive waves of the same shape and area. Alternating current has the advantage over direct current in that simpler generating machines, and generally more rugged motors, may be used; but the chief advantage is that it is possible to obtain and use very much higher voltages than can be easily obtained or used with direct current. Alternating current is, therefore, used whenever distant transmission of electric power is necessary.

ALTERNATING-CURRENT GENERATORS. See Generators, Alternating-current.

ALTERNATION. An *alternation* is an oscillation of an electric or magnetic wave from a zero to a maximum value and back to zero again. It may be positive or negative, positive alternations generally being indicated above the zero reference line, and the negative, below. There are two alternations to each cycle. See Cycle of an Alternating Current.

ALUMINA. Alumina or aluminum oxide, chemical formula Al_2O_3, occurs in nature in the mineral *corundum*. The alumina in corundum is the abrasive material which makes it useful for abrasive purposes. The abrasive material in *emery* is also alumina. See also Aluminum Oxide.

ALUMINUM. Aluminum is widely distributed in nature in combinations, especially as silicates, but is never found in the free state. Alumina or

aluminum oxide, from which aluminum is obtained, was first discovered by Marggraf, in 1754. The metal itself, however, was first discovered by Wöhler, in 1828, but it was not until about 1883 that aluminum was produced on a commercial scale. Now aluminum is produced by electrical means from bauxite, a hydrated oxide of aluminum ($Al_2O_3 + 2\ H_2O$). This mineral is widely distributed all over the world, but the most important places where it is found are in Alabama, Arkansas, and Georgia, and in the south of France and the north of Ireland. Aluminum is also contained in various other natural compounds, such as corundum, cryolite, and kaolin or china-clay.

Properties of Aluminum. — Aluminum is a white metal having a somewhat bluish luster when polished. The specific gravity of aluminum varies from 2.5 to 2.7. When cast in the pure state, it has a specific gravity of 2.58. When rolled in bars of large section, the specific gravity is about 2.6, but, when rolled into very thin sheets, it may rise to 2.69. Commercial aluminum, however, contains impurities to such an extent that the specific gravity generally varies between 2.7 and 2.8. When in the molten state, the metal expands and the specific gravity is only from about 2.43 to 2.54. As pure aluminum is lighter than the commercial product, a careful determination of the specific gravity is a good indication of the purity of the metal tested.

Aluminum is a very ductile and malleable metal; it can be made into sheets 0.000025 inch thick and drawn into wires 0.004 inch in diameter. Sheets as thin as mentioned can only be obtained by beating like gold-leaf, but sheets may be rolled down to a thickness of 0.0005 inch. The melting point of aluminum is at 1218 degrees F. (659 degrees C.). The coefficient of linear expansion, by heat, is 0.0000125 per each degree F. The mean specific heat between 32 and 212 degrees F. is 0.227, and the latent heat of fusion, 28.5 B.T.U. Aluminum is a good conductor of heat and is surpassed, in this respect, only by silver, copper, and gold. Its conductivity of heat is equal to 31 per cent of that of silver. The heat transmitted in British thermal units per second, through aluminum 1 inch thick, per square inch of surface, for a temperature difference of 1 degree F., is 0.00203 B.T.U.

Aluminum is a good conductor of electricity, its electrical conductivity being about 60 per cent of that of copper for equal volumes, or about double that of copper for equal weights. Aluminum is not magnetic. Pure aluminum, chemical symbol Al, and atomic weight 27.1, has a hardness on the Mohs scale of 2.5, this degree of hardness making it just a little too hard to be scratched by the finger nail. Impurities, however, harden the metal to a considerable extent, even when present in small quantities, and the purity of the metal is roughly estimated by the ease with which it can be cut with a

steel knife. The surface of aluminum is hardened, to a very great degree, by cold-drawing or rolling, so that the surface may obtain a hardness equal to that of brass. The numerous aluminum alloys are distinguished by their low specific gravity and high tensile strength.

ALUMINUM ALLOYS. While aluminum is valuable for many light-weight machine parts, it is soft and lacking in tensile strength and rigidity for many purposes. In order to increase the strength, and at the same time retain the valuable property of lightness, copper, manganese, iron, and nickel have been alloyed with aluminum in various proportions. By adding from 2 to 8 per cent of any of these metals, an alloy is obtained having a strength and hardness far superior to that of aluminum. Plates and bars made from these alloys have ultimate tensile strengths varying from 40,000 to 50,000 pounds per square inch with an elastic limit of from 55 to 60 per cent of the ultimate tensile strength, an elongation of 20 per cent in 2 inches, and a reduction of area of 25 per cent. As the percentage of the heavier metals that is added to the aluminum is small, the specific gravity can be kept well below 3. In fact, most of these alloys have a specific gravity of from 2.8 to 2.85. In castings, the percentage of alloying metal that must be added is greater than in plates and bars. The ultimate tensile strength of aluminum alloy castings containing zinc, iron, manganese, or copper varies from 20,000 to 25,000 pounds per square inch. If tin is added to the alloy, the shrinkage is reduced, and certain aluminum-tin alloys have less shrinkage than cast iron. There are a number of aluminum alloys that are known by specific trade names. See also Duralumin.

Aluminum-copper Alloys.—Aluminum-copper alloys are made in two series, one of which contains from 2 to 10 per cent of copper with the remainder aluminum, and another which contains from 3 to 10 per cent of aluminum with the remainder copper. The latter alloys, being high in copper, are known as *aluminum bronzes*. The series of alloys high in aluminum can be rolled into bars and made into castings. The specific gravity varies from 2.71 with 2 per cent of copper, to 2.84 with 8 per cent of copper; the tensile strength for a 2-per-cent copper alloy is 43,000 pounds per square inch; for a 6-per-cent copper alloy, 45,000 pounds per square inch; and for an 8-per-cent alloy, 56,000 pounds per square inch. The copper and aluminum in this series of alloys will separate in the cooling, and chilled molds are therefore necessary, so that the metals will not have time to separate before they solidify. The pouring of these alloys should be done at the lowest possible temperature. Just before pouring, the molten metal should be stirred with a carbon rod.

Aluminum-zinc Alloys.—Alloys of aluminum and zinc are valuable in that they resist corrosion effectively. The addition of zinc to aluminum

facilitates the production of good castings. While these metals will alloy in all proportions, only alloys containing from 15 to 33 per cent of zinc are in general use. Alloys containing less than 15 per cent of zinc are malleable and can be rolled and drawn, but the tensile strength is inferior. If dynamic as well as tensile strength is desired, the alloy should not contain less than 20 per cent of zinc. With 15 per cent of zinc, the tensile strength is about 22,000 pounds per square inch; the elastic limit, about 16,000 pounds per square inch; the elongation in two inches, 6 per cent; and the reduction of area, 10.5 per cent. An alloy of zinc and aluminum containing 25 per cent of zinc can be rolled into bars and drawn into wire, and is probably the zinc-aluminum alloy most generally used. When cast in sand molds, this alloy has a tensile strength of 27,000 pounds per square inch; an elongation in two inches of 1 per cent; and a reduction in area of 3 per cent; the specific gravity is 3.4. Chilled castings have been made having a tensile strength of 40,000 pounds per square inch. Alloys containing from 10 to 30 per cent of zinc can be easily worked in machine tools and, in most cases, without cutting lubricants. The addition of a small percentage of copper to aluminum-zinc alloys greatly increases the tensile strength. One disadvantage of the aluminum-zinc alloys is that they lose their strength rapidly with rising temperature; even an increase of 100 degrees F. over ordinary room temperature produces a marked effect.

ALUMINUM ALLOYS FOR AUTOMOBILE PARTS. The S.A.E. aluminum alloy specification No. 30 is used more extensively in the automotive industry of the United States than all other light-casting alloys combined. The composition in percentages follows: Aluminum, minimum, 90; copper, 7.00 to 8.50; zinc, maximum, 0.20; silicon, iron, zinc, manganese and tin, maximum, 1.70; other impurities, none.

This alloy is used for crankcases, oil-pans, steering-wheel spiders, differential carriers, transmission cases, camshaft housings, hub caps, and similar parts. Its specific gravity is about 2.83 and the tensile strength of test specimens about ½ inch in diameter, cast in sand and tested without removing the skin, should be about 18,000 to 20,000 pounds per square inch, with an elongation of 1 to 2 per cent in 2 inches.

S.A.E. specification No. 31, which is extensively used in England for crankcases, transmission cases, oil-pans, steering-wheel spiders, etc., has a smaller amount of aluminum and a much larger percentage of zinc. The composition in percentages follows: Aluminum, minimum, 81; copper, 2.25 to 3.25; zinc, 12.50 to 14.50; silicon, iron, manganese and tin, maximum, 1.70; other impurities, none. The specific gravity is about 3 and the tensile strength of test specimens ½ inch in diameter, cast in sand and tested without

removing the outer skin, should be 25,000 to 30,000 pounds per square inch. The pattern shrinkage allowance for both specifications Nos. 30 and 31 is $\frac{5}{32}$ inch per foot.

Castings Having Thin Sections. — An aluminum alloy intended for automobile body parts and other members that must be cast in thin sections has the following composition, which represents the S.A.E. standard specification No. 35: Aluminum, minimum, 92.50 per cent; copper, maximum, 0.60 per cent; iron, maximum, 1.00 per cent; silicon, 4.50 to 6.50 per cent; zinc, maximum, 0.20 per cent; manganese, maximum, 0.20 per cent. This alloy withstands salt-water corrosion very well and is therefore suitable for aircraft engine parts or other parts that may be subjected to severe corroding influences. The alloy has a relatively low yield-point and cannot be used where great strength or stiffness is required.

ALUMINUM ANNEALING. Correct annealing of aluminum is dependent upon both time and temperature. Frequently the length of the annealing period has a more important bearing on the mechanical properties than has the temperature. Although aluminum is distinctly a malleable metal, it frequently is necessary to anneal it two or three times during the forming of an intricate piece. The procedure is to work the piece to a certain stage, anneal it, and repeat the process until the desired shape is obtained. Sheet aluminum can be annealed most efficiently in a muffle furnace, where the heat can be obtained by radiation. If such a furnace is not available, the work may be annealed quite satisfactorily in an open fire of clean coke, over a brazier's gas hearth, or over the flame of the benzoline or gasoline blow-torch. Owing to the relatively low melting point of aluminum, which is approximately 1210 degrees F., great care must be taken during annealing to prevent the metal from melting. The annealing temperature varies from 700 to 900 degrees F., depending on the thickness of the metal and the length of time that it is subjected to the heat. Tests have shown that short exposures in the annealing temperature, ranging from three to thirty minutes, confer workable properties on the metal.

ALUMINUM BRASS. This alloy consists of 70.5 per cent of copper; 26.4 per cent of zinc; and 3.1 per cent of aluminum. It is used in cases where an accurately-sized casting is required. The alloy can also be rolled and forged hot, when the aluminum content does not exceed that specified. In aluminum brasses where the percentage of aluminum exceeds 4 per cent, it cannot be worked easily. The tensile strength of aluminum brass is about 42,000 pounds per square inch with an elastic limit of about 17,000 pounds per square inch, and an elongation of 50 per cent.

ALUMINUM BRONZE. This is one of a number of alloys in which aluminum is alloyed in small percentages with another metal which forms

the base. It contains from 5 to 11 per cent of aluminum, the remainder being copper, and is a very dense, fine-grained and strong alloy. With 10 per cent of aluminum, forged bars will have a tensile strength of 100,000 pounds per square inch and an elastic limit of 60,000 pounds per square inch, with an elongation of 10 per cent in 8 inches, and a specific gravity of about 7.5. If from 5 to 7.5 per cent of aluminum is used, the specific gravity will be from 8 to 8.30, with a tensile strength of from 78,000 to 80,000 pounds per square inch, an elastic limit of 40,000 pounds per square inch, and an elongation of 30 per cent in 8 inches. Alloys containing 95 per cent of copper and 5 per cent of aluminum have a tensile strength of about 55,000 pounds per square inch and an elastic limit of about 25,000 pounds per square inch. The values for tensile strength given above for aluminum bronzes are based upon tests with specially high-grade material made from very pure metals and cannot be expected to be obtained in all cases in the commercial brass foundry. It is safe to say, however, that aluminum bronzes will have a tensile strength of from 40,000 to 60,000 pounds per square inch with an elongation of from 10 to 20 per cent in 8 inches. Aluminum bronze can be drawn into wire which is used for electrical resistance coils. The alloy withstands intense heat for an unlimited time without injury. If more than 11 per cent of aluminum is added to copper, the alloy is too brittle to be of any commercial value. With an aluminum content of about 9 or 10 per cent, the best all-around results are obtained.

ALUMINUM BRONZE, WROUGHT. According to the S.A.E. standard specification No. 69 wrought aluminum bronze should have the following composition: Copper, 85.00 to 87.00 per cent; aluminum, 7.00 to 9.00 per cent; iron, 2.50 to 4.50 per cent; tin (none desired), maximum, 0.50 per cent; other impurities, maximum, 0.25 per cent. Wrought shapes as well as rods and bars made of this alloy combine unusual strength with good anti-corrosive qualities. Wrought bars when annealed or hot rolled should have a minimum ultimate strength varying from 72,000 to 80,000 pounds per square inch, depending upon the diameter or thickness of the bar.

ALUMINUM CASTINGS. Aluminum can be melted in ordinary plumbago crucibles the same as brass, but care must be taken not to heat it more than is absolutely necessary, as it is injured by overheating. The melting temperature (about 1215 degrees F.) should, therefore, not be much exceeded, and the metal should be poured at as low a temperature as possible, as this will aid in avoiding blow-holes. The shrinkage in cooling is $\frac{17}{64}$ inch per foot, or slightly more than for brass. It is best cast in green sand molds, lightly rammed. Vertical risers and gates of ample size are required and the molds should be faced with plumbago or French chalk. Iron molds can also be used for casting aluminum. Pin holes are caused in the castings,

by allowing the metal to remain in the fire for some time after it is melted; the metal should, therefore, be removed from the fire as soon as it is in the molten state. The most frequent cause of cracking of aluminum castings is also due to overheating of the metal while melting. Aluminum castings, as a rule, do not consist of a pure or even commercially pure aluminum, but the aluminum generally contains a small amount of zinc and, occasionally, copper. The presence of zinc renders the casting more liable to crack, but, on the other hand, greater strength in the metal is obtained by the use of the zinc. In placing the ingots of aluminum in the crucible, they should be packed as compactly as possible so that no portions of the metal will project above the mass and become exposed to the action of the flame.

ALUMINUM-COPPER CASTINGS. As far as can be estimated from available figures, according to a publication "Preparation of Light Aluminum-Copper Casting Alloys," published by the United States Bureau of Mines, about 97 per cent of all aluminum-copper alloys are made from an alloy containing approximately 92 per cent aluminum and 8 per cent copper. Among the other alloys used for commercial castings are those containing from 2 to 13.5 per cent copper, the remainder being aluminum. The 96–4 aluminum-copper alloy is used extensively for sand-cast cooking utensils. In this country a favorite motor-piston alloy is made with from 9 to 10.5 per cent copper and the remainder aluminum, but some plants introduce iron as well as copper to increase the hardness. The consensus of opinion among foundrymen seems to be that the 92–8 aluminum-copper alloy is the best available for general casting purposes.

ALUMINUM DIE-CASTING ALLOY. See Die-casting Alloy, Aluminum-base.

ALUMINUM DISCOVERY. The discovery of aluminum is generally credited to Wohler in 1827, but the claim has also been made that the metal was first prepared by Oersted in 1825. Results of certain experiments made by Oersted were published in the early part of 1825, and a specimen of the new metal was presented to the Danish Society of Sciences at that time. In 1826, Oersted published a paper in which he described the properties of the metal that he had obtained, stating that it had a distinct metallic luster.

ALUMINUM, GUN-METAL FINISH. See Gun-metal Finish on Aluminum.

ALUMINUM OXIDE. Artificial abrasives of the aluminum oxide class, are produced in electric furnaces from bauxite, which is a soft earth, and is the purest form of aluminum oxide found in nature. The oxide crystallizes when bauxite is fused in the electric arc furnace, and because of the abrasive being artificially produced, undesirable elements can be eliminated. It

is due to this fact that artificial abrasive wheels have become popular. Crystalline aluminum oxide ranges in color from white to deep wine color. Wheels made from this abrasive are recommended for grinding materials having a high tensile strength, including the various steels, annealed malleable iron, wrought iron, tough bronzes and tungsten. Aluminum oxide grains are hard, tough, and dense, and when fractured, leave sharp cutting edges.

ALUMINUM PAINT. Aluminum paint is opaque to sunlight and possesses high heat and light reflecting qualities. The high light reflectivity makes the paint particularly satisfactory for painting dark buildings, rooms, mills, etc. High reflectivity also means low absorption; therefore, when a tank or other chamber should be kept cool inside, this is facilitated by painting the outside with aluminum paint. It is the reason that an increasing number of gas and oil storage tanks and oil-tank cars are being painted with aluminum paint. In investigations conducted on oil storage tanks in the southwest, by the United States Bureau of Standards, it was found that the temperature of oil in tanks coated with aluminum paint was several degrees lower than in tanks coated with other paints. Furthermore, due to the lower temperature, there is a much smaller loss of the highly volatile oils from tanks coated with aluminum paint.

It is evident from the foregoing that aluminum paint should not be used on radiators. See Radiation of Heat.

ALUMINUM PISTON ALLOYS. The two chief difficulties in producing suitable aluminum alloy pistons have been, first, to obtain an alloy that would meet all the requirements of an automobile engine piston and, second, to so design the piston as to meet the special qualities of the metal and the needs of the service. The alloy must, of course, resist such shocks as are met with in internal combustion engines and at the same time must have a high thermal conductivity. The coefficient of thermal expansion must be similar to that of cast iron. The National Physical Laboratory advocates an aluminum alloy consisting of 4 per cent of copper, 2 per cent of nickel, and 1.5 per cent of manganese, the remainder being aluminum. This material, when cast in 1-inch diameter chill-cast bars, has an ultimate strength, at 250 degrees C. (482 degrees F.), of about 25,000 pounds per square inch. Experiments have shown that the clearance of aluminum pistons should be about 50 per cent greater than that necessary for cast-iron pistons.

ALUMINUM SOLDERING. Some fractured and defective aluminum alloy castings can be repaired quite satisfactorily by the oxy-acetylene process, but often it is undesirable to heat the parts to the relatively high temperature necessary for welding, because of the resulting distortion. In such cases, a means of joining the parts without heating them to a high

temperature is desirable. Aluminum parts can be permanently repaired by soldering when the solder can be made to adhere to the aluminum and when the joint thus made is not subject to deterioration. Aluminum cannot be soldered by the same process as that which the tinsmith uses in soldering tin and copper with a hot copper bit and a solder that will flow and follow the copper. The practice with aluminum is more like brazing with hard solders.

A solder joint in aluminum, on exposure to moisture, will not remain permanent, as galvanic cells are set up which cause the joint to become rapidly disintegrated by auto-corrosion. One of the most severe tests to which a solder joint can be subjected is that of placing it in steam; hence solder joints should be protected against corrosion by a bitumastic paint or varnish.

Aluminum Solder. — A suitable solder for joining aluminum may be composed solely of tin and zinc, the amount of zinc employed ranging, perhaps, from 15 to 50 per cent. Another solder for aluminum consists of a mixture of tin, zinc, and aluminum. In this mixture, the amount of zinc may vary from 8 to 15 per cent, and the aluminum from 5 to 12 per cent. The tensile strength of a good aluminum solder is about 7000 pounds per square inch. It is desirable that the solder should not be brittle and it is best applied without a flux.

The process of tinning is accomplished by heating the surfaces to be joined with an atmospheric gas torch or a kerosene blow-torch, to a temperature somewhat above the fusing point of the solder, and then rubbing the surface with the point of a tinned steel tool which serves to remove the outside film and allows the solder to act upon the clean surface. The higher the temperature— within certain limits — at which the tinning is done, the better will be the adhesion of the tinned layer. After the surfaces to be joined have been properly tinned, they are joined by pressing them together and again heating to the required temperature, as determined by the composition of the solder. If necessary, the joint may be smoothed with a spatula just before the solder hardens, care being taken not to move the work until the solder has become thoroughly set.

ALUMINUM WELDING. The successful welding of aluminum alloy castings by the oxy-acetylene process, depends a great deal upon the success achieved in breaking down the aluminum oxide, the forming of which is intensified as soon as the oxy-acetylene torch flame comes in contact with the metal. It is this oxide film that prevents the proper flow of the metal at the welding temperatures and that has been the cause of many failures in aluminum welds.

Cleaning Surfaces. — The surfaces to be joined must be thoroughly cleaned and the material near the surfaces to be welded must also be clean, as other-

wise the impurities near the joint will invariably set up auto-corrosion in the weld. Oily machine parts should be allowed to remain for a few seconds in a hot 10 per cent caustic soda solution, after which, the castings should be thoroughly washed and scrubbed in plenty of clean hot water. It is often advisable first to wash the oily castings with gasoline to remove the greater part of the grease and dirt.

Joint Beveling. — After the work is cleaned, a V-shaped groove is filed or chipped along the crack or seam to the bottom to permit the metal to be melted the full depth of the work. However, aluminum alloy castings up to $\frac{1}{4}$ inch in thickness can be welded with the torch flame without beveling the joints.

Preheating. — In welding aluminum and aluminum alloy castings, it is necessary to preheat and anneal the work in order to prevent too rapid expansion and contraction of the metal. Preheating also conserves gas, increases the rate of welding, and prevents warping. Great care, however, must be exercised to avoid exceeding a temperature of 750 and 840 degrees F., respectively, when preheating and reheating or annealing the work. At higher temperatures a piece of work may be rendered useless by deformation. During the preheating of castings of complex shape or castings that vary greatly in thickness, the casting should be covered with sheet asbestos to keep the temperature as uniform as possible. The asbestos should not be removed during the welding operation, except as it is necessary to effect the weld.

Welding Procedure. — A puddling rod, made from a piece of mild steel rod $\frac{3}{16}$ or $\frac{1}{4}$ inch in diameter and flattened on one end like a flat scraper, is used in welding to scrape and agitate the metal at the moment of melting in order to break up the oxide and allow the molten metal to flow together. It is necessary to wipe the puddling rod frequently to prevent it from becoming coated with oxide, and care must be taken not to allow it to reach a red heat, as otherwise oxide of iron will be formed on it which might result in a defective weld. The oxide formed in the course of melting aluminum offers considerable resistance to the welding flame, and it must be eliminated to effect a homogeneous weld. This is best done by employing an aluminum alloy welding flux which dissolves and deoxidizes the layer of oxide adjacent to the joint to be welded, at the temperature at which the aluminum reaches a molten state.

The welding material, usually a rod or broken aluminum part, should be of as pure aluminum as it is possible to obtain and the end of the rod should be kept in the molten bath while welding. For aluminum alloy castings, the welding material should be of approximately the same composition as the alloy to be welded.

Flame Adjustment. — In making a weld, the torch flame should be so ad-

justed that it will furnish a slight excess of acetylene, and it is essential to avoid contact of the white-hot bulb or cone with the metal that is about to become molten, because the hot temperature in this part of the flame tends to produce holes in the metal which are often difficult to repair. The correct distance varies according to the size of torch tip employed, but in general, the distance should be from $\frac{1}{4}$ to $\frac{3}{4}$ inch. After welding, the casting should be reheated evenly and allowed to cool very slowly. When the casting is cold, it should be thoroughly washed in hot water to remove all traces of the flux, which would otherwise continue to produce a chemical action on the metal that would result in harmful corrosion.

ALUMINUM WELDING FLUXES. The oxide formed in the course of melting aluminum offers considerable resistance to the welding flame. It does not always rise to the surface, especially if the work is thick, yet it must be eliminated to effect a homogeneous weld. This is done by employing a flux which dissolves and deoxidizes the layer of oxide adjacent to the joint to be welded, at the temperature at which the aluminum reaches a molten state. Another function of a flux is to protect the fused metal from contact with the air.

An example of a good flux for aluminum and aluminum alloys with a melting point of approximately 1110 degrees F. is one containing a mixture of lithium chloride, potassium chloride, potassium bisulphate, and potassium fluoride. The reactions that take place in the application of such a flux are believed to be as follows: The potassium fluoride reacts with the potassium hydrogen sulphate, forming hydrofluoric acid, and this immediately acts on the aluminum oxide, forming aluminum fluoride, which is free to combine with the excess of potassium fluoride existing in the flux, forming potassium aluminum fluoride, which is capable of dissolving a further quantity of aluminum oxide. The lithium chloride and potassium chloride serve the purpose of lowering the fusion point of the mixture.

When castings that have sand on their surface are to be welded, a flux that will remove the sand must be used. If the sand is not removed, it is in part reduced, resulting in silicon being passed into the metal — a condition that often reduces the strength of the weld an appreciable amount. A flux that is adapted for use under these conditions is composed of potassium chloride or fluorspar. This flux will prevent silicon from entering the alloy.

The flux may be applied in paste form to the surfaces to be welded, or the parts may be heated and the powdered flux sprinkled over the joint, or the end of the welding rod may be heated and dipped into the flux, which readily adheres to it in the form of a thin varnish; the last method is the safest and best. The powdered fluxes should be kept free from dust and dirt, and preferably in air-tight containers, as they absorb moisture rapidly.

ALUNDUM. Alundum is an artificial abrasive made in the electric furnace by the fusion of a mineral called *bauxite*, which was considered infusible until the invention of the electric furnace. Alundum is the oxide of aluminum in crystalline formation. The bauxite is given a preliminary heating in large furnaces, to dry off the combined water, and it is then melted in electric furnaces. The temperature at which the furnace charge melts into one homogeneous mass is estimated to be between 6000 and 7000 degrees F. When the large masses of molten bauxite become cool, they are then crushed, washed, and graded. The physical formation of a grain of alundum is such that a fracture leaves sharp cutting corners or edges. Alundum has a high melting point, high thermal conductivity, a low coefficient of expansion, and is a non-conductor of electricity. These properties make it of value in the manufacture of all kinds of refractory materials, for general laboratory use, and for electric furnace parts, etc. While grinding wheels made of alundum are used for a great variety of work, they are especially adapted for the grinding of steel or other materials of high tensile strength.

ALZENE. An alloy consisting of two parts of aluminum and one part of zinc has been given the trade name "alzene." It is equal in strength to good cast iron and superior to it in the matter of elastic limit. It is very stiff and has a fine-grained structure. It has no elongation, however, but breaks off "short" like cast iron, and should, therefore, not be used where it is subjected to shocks.

AMALGAMS. Alloys formed by mercury and other metals are known as "amalgams." Many of these are formed by direct contact of a metal with mercury; others are formed when the metal and mercury are placed together in dilute acid. In still other cases, mercury is added to the solution of a metallic salt, or the metal is added to the solution of mercury nitrate. When newly made, amalgams are plastic, but they harden after a short time and then usually either expand or contract to a considerable extent. The most common metals that combine with mercury to form amalgams useful in the industries are tin, copper, cadmium, bismuth, silver, and gold. Tin amalgam is used for silvering mirrors. Copper and cadmium amalgams are used in dentistry, silver and gold amalgams are used in silvering and gilding, and an amalgam of zinc and tin is used in electrical machinery. Zinc plates of electric batteries are covered with an amalgam in order to reduce the polarization. Many amalgams are useful as cements for metals, the cement being applied in its plastic form when newly made, and hardening after a short interval, as mentioned.

AMBROIN. Ambroin is an electric insulating material which will resist high temperatures. Its puncturing voltage exceeds 5000 volts per millimeter (0.039 inch). This material is made by baking silicate of sodium,

asbestos, etc., mixed with alcohol, in a vacuum. It is then molded in heated molds at high pressure. Its tensile strength is given as about 2100 pounds per square inch, and its compressive strength as about 2700 pounds per square inch, at ordinary temperatures. It is only slightly affected by the moisture of the atmosphere.

AMERICAN STANDARD SCREW THREADS. The National Screw Thread Commission was authorized by Congress in 1918 for the purpose of establishing screw thread standards for the use of manufacturers and various branches of the Federal Government. The aim of the commission in establishing thread systems was to eliminate all unnecessary sizes and to utilize as far as possible present predominating sizes. In 1920, the Society of Automotive Engineers and the American Society of Mechanical Engineers, acting as joint sponsors, organized the Sectional Committee on Standardization and Unification of Screw Threads under the procedure of the American Engineering Standard Committee. This Sectional Committee was formed for the purpose of reviewing the " Progress Report " of the National Screw Thread Commission.

As the result of this cooperation between the National Screw Thread Commission and the Sectional Committee referred to, certain modifications were made in the original or tentative screw thread system, all changes having been in agreement with the National Screw Thread Commission. These changes included a change of the name used in designating the standard, from National to American, or American (National), the latter form being applied particularly to the form of thread. Following is a summary of the outstanding features of this system as approved by the American Engineering Standards Committee.

Form of Thread. — The form of thread profile which is designated as the American (National) form, is the same as the U. S. Standard or Sellers profile. It is recommended that this form be used wherever possible for screw thread work. Clearance for the nut is to be provided at the minor diameter by removing the thread form at the crest by an amount between $\frac{1}{6}$ and $\frac{1}{4}$ of the basic thread depth. Clearance for the nut is also provided at the major diameter by decreasing the depth of the truncation triangle any desired amount down to $\frac{1}{3}$ of its theoretical value.

Thread Series Adopted. — Two thread series have been adopted, one being coarse and the other fine. The coarse thread series is the present United States Standard, supplemented in sizes below $\frac{1}{4}$ inch by a part of the standard established by the American Society of Mechanical Engineers in 1907. The fine thread series for diameters from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches, inclusive, is in accordance with the present " regular " screw thread series of the S.A.E. Standard for Screw Threads, established by the Society of Automotive

Engineers in 1911, and below $\frac{1}{4}$ inch the fine thread series is supplemented by the fine thread series established by the American Society of Mechanical Engineers.

Classification of Fits. — Four distinct classes of screw thread fits are included in the American Standard. The *loose fit* (class 1) is recommended as a commercial standard for tapped holes in the numbered sizes only, but it may be used with screws of other classes to obtain the quality of fit desired. This fit is recommended whenever an allowance is required between the maximum screw and minimum nut and in cases where larger tolerances than those given for the free fit are needed.

The *free fit* (class 2) includes the large bulk of screw thread work of ordinary quality of finished and semi-finished bolts, nuts, etc. (This was designated as a medium fit (regular) in the National Screw Thread Commission's Progress Report, which has been referred to previously.)

The *medium fit* (class 3) includes the better grade of interchangeable screw thread work, such as automobile bolts and nuts. (This was called medium fit (special) in the National Screw Thread Commission's Progress Report.)

The *close fit* (class 4) includes screw thread work requiring a fine snug fit that is somewhat closer than the medium fit and is desired for high-grade aircraft parts, etc. In this class of fit selected assembly of parts may be necessary. It is not considered practicable for commercial standards of tapped holes of the numbered sizes.

Tabulated Data. — The tabulated data for the American Standard include tables of allowances and tolerances for the loose, free, medium and close fits, and, in addition, the various diameters of different sizes, for obtaining the different classes of fits, there being tables for both screws and nuts. The coarse thread series is recommended for use with free fit tolerances and medium fit tolerances. Its use with close fit tolerances is also permissible. The fine thread series is recommended for use with medium fit tolerances and close fit tolerances. Its use with free fit tolerances is also permissible.

AMERICAN STANDARD TAPER PIPE THREAD. The American standard taper pipe thread is the same as the American Briggs standard. The form of the thread is a 60-degree vee, truncated equally top and bottom by an amount equal to 0.033 times the pitch of the thread. The taper of the thread, on the diameter, is $\frac{1}{16}$ inch per inch or $\frac{3}{4}$ inch per foot. As far as the thread on the product is concerned, no change has been made from the former American Briggs standard; but to allow for a reasonable amount of wear on the taps and dies, thus making for more economical production, a modification has been made on the gages. This consists of reducing the crest of the thread gage by truncating it an amount equal to 0.10 times the pitch from

the theoretical sharp point. If an old gage is correct in all other respects, it can easily be made to conform to the present standards by grinding off the excess metal at the crests of the threads. This taper thread can be used for threaded joints for any service.

AMERICAN STEEL AND WIRE CO.'S GAGE. The Bureau of Standards at Washington recommends that this be referred to as Steel Wire Gage, which see.

AMERICAN WIRE GAGE. This gage is used for bare and insulated wire of aluminum and copper; for all bare wire made of brass, phosphor-bronze, German silver, or zinc; for resistance wire of German silver or other alloys; for rods of brass, copper, and aluminum; for sheets of brass, phosphor-bronze, aluminum, and German silver. The American Wire Gage is also known as the Brown & Sharpe.

AMMETER. An ammeter or ampere-meter is an instrument for measuring the rate of flow of electric current in amperes. Several different forms of this device have been constructed, the fundamental types of which are the Weston meter, the Thomson meter, the dynamometer, and the hot-wire meter. In the Weston meter a stationary permanent magnet acts upon a movable wire coil which is shunted by a low resistance. This meter is used for direct current only. The Thomson meter consists of a small movable piece of soft iron which is acted upon by an inclined stationary wire coil through which the current to be measured passes. The dynamometer consists of a movable and a stationary wire coil acting magnetically upon one another. The coils are connected in series, the movable coil carrying the indicating needle. In the hot-wire meter, the current passes through a straight wire, and the amperage is measured by the expansion of the wire caused by the heating effect of the current. The expansion is transmitted by a lever to an indicating needle. Suitable scales are provided in all instances, so that the amperage may be read off directly.

AMORTISSEUR WINDING. In electrical machinery, amortisseur winding is used for making synchronous motors self-starting and for preventing hunting of synchronous generators, caused by an irregularity in the operation of the prime mover. The winding is generally of the squirrel-cage type and consists of two metal rings into which are welded or riveted bars of copper, bronze, or other alloy of different resistance. The bars are imbedded in the pole faces of the machine, as near to the surface as practicable, and parallel to the armature slots.

AMPERE. The unit of the rate of flow of an electric current, known as the *ampere*, is one-tenth of the unit of current in the centimeter-gram-second system of electro-magnetic units. It is the practical equivalent of a current

which, when passed through a solution of nitrate of silver in water, deposits silver at the rate of 0.001118 gram per second. The current of an ampere will be produced by an electromotive force of one volt applied to a conductor, the resistance of which is one ohm. An ampere is also equal to the flow of a quantity of electricity of one coulomb per second. The current in amperes is measured by *ampere-meters*, also known as *ammeters*.

AMPERE-HOUR. The quantity of electricity corresponding to one ampere flowing for one hour; it is equal to 3600 coulombs.

AMPERE-HOUR METERS. Ampere-hour meters are of two general types, the *electrolytic* and the *motor-types*. Their use is now confined practically to direct-current circuits, chiefly in connection with storage batteries or other electrolytic applications. Abroad, they have been used to some extent in the place of watt-hour meters, by assuming a fixed supply voltage. Ampere-hour meters of the electrolytic type operate on the principle of the *voltameter*, the weight or volume of the products of chemical decomposition being proportional to the ampere-hours. Motor-type ampere-hour meters are of the *commutator* and the *mercury-motor* types. In the former, a permanent magnet furnishes the field in which rotates an armature carrying a small current diverted from a shunt in the main circuit. In mercury ampere-hour meters, a rotor (usually a copper disk but sometimes a cup), is submerged in mercury contained in a chamber. Current terminals are so introduced into the chamber that the current is led through the rotor, entering and leaving by way of the mercury which serves as a contact maker. The rotor is placed in the field of a permanent magnet, rotation resulting from the interaction of the current in the rotor with the magnetic field. By the use of shunts, the meter is adapted to measure larger currents than can be handled directly.

AMPERE-SECOND. The quantity of electricity corresponding to one ampere flowing for one second. It is equal to one *coulomb*.

AMPERE-TURN. The unit of magnetomotive force. The number of ampere turns of a circuit equals the product of the number of amperes flowing in the circuit multiplied by the number of turns in the circuit.

ANACONDA CONVERTER. A barrel-shaped converter similar to a Bessemer converter, used in the refining of copper by the *Manhès process*, this name being given to this type of converter because of its general use in the Anaconda mining region in Montana.

ANALYSIS, MAGNETIC-MECHANICAL. See Magnetic-mechanical Analysis.

ANALYTICAL CHEMISTRY. That part of chemistry which deals with the methods for determining the components of a substance. Analytical chemistry determines not only the kinds of elements that may be present in a substance, but also the amount of each.

ANALYTICAL GEOMETRY. That part of the science of mathematics in which the location of points, lines, and surfaces is expressed by means of equations, and in which the geometrical properties can therefore be investigated by means of algebraic operations, or algebraic expression be shown graphically by means of points or lines. In analytical geometry, the location of a point is given by stating its distance from two lines or axes which intersect each other in the case of plane analytical geometry, and from three axes intersecting at one point in the case of analytical geometry in three dimensions.

ANEMOMETER. The anemometer is an instrument for measuring the velocity or pressure of the wind, and may also be used for measuring the velocity of air in pipes of large diameter. Experiments have shown, however, that anemometers are not reliable for the measurement of velocities of air in pipes, especially when the diameters do not exceed 24 inches, the instrument generally giving too low results when used in this manner. It has also been found that the percentage of error is not constant, but varies considerably with the diameter of the pipe and the speed of the air. Anemometers are divided into two main classes, those that measure the velocity and those that measure the pressure of the air or wind. There is, however, a close relationship between the pressure and the velocity, so that an instrument of either class can easily be made to give direct readings for both of these quantities.

ANGLE. When two lines intersect, an angle is formed between them. The point where the two lines intersect is called the *vertex* of the angle. Angles are measured in degrees, minutes, and seconds (1 degree = 60 minutes; 1 minute = 60 seconds). A 90-degree angle is known as a *right* angle. Angles larger than 90 degrees are called *obtuse* angles, and those less than 90 degrees, *acute* angles. The two lines forming an angle are called the *sides* of an angle. The sides of a 90-degree angle are *perpendicular* to each other.

ANGLE DIAMETER. The pitch diameter of a screw thread is sometimes called the "angle diameter," because it is measured in the angle of the thread either by using a special type of micrometer or by means of the well-known three-wire method. The pitch or angle diameter is the diameter measured halfway between the theoretical top and bottom of a screw thread, and, therefore, equals the theoretical outside diameter minus the thread depth. The term "pitch diameter" is recommended. The pitch

diameter of a straight screw thread is the diameter of an imaginary cylinder the surface of which would pass through the threads at such points as to make equal the width of the threads and the width of the spaces cut by the surface of the cylinder.

ANGLE OF ADVANCE. The angle of advance, or "angular advance," as it is sometimes called, is generally considered the angle through which the eccentric of a steam engine must be turned to move the valve from its mid-position to the position which it occupies at the beginning of the piston stroke. This movement of the valve on its seat equals the outside lap plus the lead; hence, the angle of advance equals the angle due to the outside lap plus the angle due to the lead. The total angle between the crank and eccentric is sometimes referred to as the angle of advance. The definition first given, however, is generally considered correct, and is more convenient to use in connection with valve diagrams and the study of valve motions, in general.

ANGLE OF REPOSE. If a body is placed on an inclined plane, the friction between the body and the plane will prevent it from sliding down the inclined surface, provided the angle of the plane with the horizontal is not too great. There will be a certain angle, however, at which the body will just barely be able to remain stationary, the frictional resistance being very nearly overcome by the tendency of the body to slide down. This angle is termed the *angle of repose* and the tangent of this angle equals the coefficient of friction. The angle of repose is frequently denoted by the Greek letter θ. Thus, $\mu = \tan \theta$. A greater force is required to start a body from a state of rest than to merely keep it in motion, because the *friction of rest* is greater than the *friction of motion*.

ANGLE PLATE. A cast iron or forged piece having two surfaces at an angle to each other, usually a right angle, and used for holding work to be machined. One face is clamped to the machine face-plate or table and the work is supported by the other face.

ANGLES, FUNCTIONS. See Functions of Angles.

ANGLE SHEARS. What are known as *angle shears* are designed especially for cutting angle iron and similar shapes. A common form of machine has two cutter-slides which move downward at an angle of 45 degrees with the work table.

ANGLE, STRUCTURAL. This is one of the common standard structural sections. See Structural Shapes.

ANGULAR VELOCITY. The angular velocity of a rotating body is expressed in angular measure and equals the angle through which any

radius of the body turns in one second. This angle is generally expressed in radians.

$$\text{One radian} = \frac{180}{\pi} = \frac{180}{3.1416} = 57.3 \text{ degrees.}$$

The angular velocity in radians is generally denoted by the Greek letter ω. If r = radius of revolving body in feet; n = number of revolutions per minute; and v = velocity of a point on the periphery, in feet per second; then,

$$v = \frac{2\pi r n}{60}; \qquad \omega = \frac{v}{r} = \frac{2\pi n}{60}; \qquad v = \omega r.$$

ANHYDRID. An oxide which unites with water to form an acid. Generally these oxides are non-metallic, although sometimes metallic oxides are anhydrid.

ANIMAL GLUE. See Glues for Wood.

ANNEALING. Annealing involves reheating and cooling of metals which are in the solid state. Annealing usually implies relatively slow cooling as compared, for example, with normalizing, and the purpose of annealing may be either (1) to remove stresses, (2) to soften a metal as for machining, (3) to change the ductility, toughness, electrical, magnetic or other physical properties; or (4) to refine the crystalline structure. The annealing temperature and rate of cooling depend upon the material and purpose of the treatment.

A common method of annealing steel is to pack it in a cast-iron box containing some material, such as powdered charcoal, charred bone, charred leather, slacked lime, sand, fireclay, etc. The box and its contents are then heated in a furnace to the proper temperature, for a length of time depending upon the size of the steel. After heating, the box and its contents should be allowed to cool at a rate slow enough to prevent any hardening. It is essential, when annealing, to exclude the air as completely as possible while the steel is hot, to prevent the outside of the steel from becoming oxidized.

The temperature required for annealing should be slightly above the critical point, which varies for different steels. Low-carbon steel should be annealed at about 1650 degrees F., and high-carbon steel at between 1400 and 1500 degrees F. This temperature should be maintained just long enough to heat the entire piece evenly throughout. Care should be taken not to heat the steel much above the decalescence or hardening point. When steel is heated above this temperature, the grain assumes a definite size for that particular temperature, the coarseness increasing with an in-

crease of temperature. Moreover, if steel that has been heated above the critical point is cooled slowly, the coarseness of the grain corresponds to the coarseness at the maximum temperature; hence, the grain of annealed steel is coarser, the higher the temperature to which it is heated above the critical point. If only a small piece of steel or a single tool is to be annealed, this can be done by building up a firebrick box in an ordinary blacksmith's fire, placing the tool in it, covering over the top, then heating the whole, covering with coke and leaving it to cool over night. Another method is to heat the steel to a red heat, bury it in dry sand, sawdust, lime, or hot ashes, and allow it to cool.

ANNEALING ALUMINUM. See Aluminum Annealing.

ANNEALING CHAINS. See Chain Annealing.

ANNEALING HIGH-SPEED STEEL. Experiments to determine the temperature to which high-speed steel should be heated for annealing, indicated that when this steel was heated to below 1250 degrees F. and slowly cooled, as in annealing, it retained the original hardness and brittleness imparted to the steel in forging. When heated to between 1250 and 1450 degrees F., the Brinell test indicated that the steel was soft, but impact tests proved that the steel still retained its original brittleness. However, when heated to between 1475 and 1525 degrees F., the steel became very soft, it had a beautiful fine-grained fracture, and all of the initial brittleness had entirely disappeared. In carrying these tests further, to 1600, 1750, and 1850 degrees F., it was found that the steel became very soft, but there was a gradual increase in brittleness and in the size of the grain, until at 1850 degrees F. the steel became again as brittle as unannealed steel; the fracture at this temperature was dull, dry, and lifeless, and showed marked decarbonization. Dried air-slacked lime was used as a packing medium in making these tests. The steel was packed in tubes both ends of which were afterward provided with air-tight caps. The decarbonization that took place was probably due to the oxygen in the air that had filled the intervening spaces between each minute particle of lime, before it was packed in the tube, attacking the carbon of the steel; this decarbonization would not have taken place if powdered charcoal had been used. The latter would have supplied all the carbon necessary to combine with any oxygen present in the tubes.

ANNEALING MALLEABLE IRON CASTINGS. Annealing of malleable iron castings is heat-treatment designed to produce tough and ductile malleable iron from hard castings. This change is brought about by changing the pearlite and cementite of the iron to ferrite and temper carbon, which is done by heating the castings up to the temperature at which the ce-

mentite breaks down into iron and carbon. For furnace malleable castings, the temperature is maintained from 1450 degrees F. to a maximum temperature of 1600 and in some cases 1650 degrees F.

Malleable iron usually has a white outer band, approximately $\frac{1}{64}$ inch thick, followed by a dark gray band and a velvety black interior. As the annealing proceeds, the steel band around the casting becomes thicker and the gray band thinner.

ANNEALING, WATER METHOD. Quick annealing can be partially effected by what is known as "water annealing." The steel is slowly heated to a cherry red, and is then removed from the furnace. A piece of soft wood is used to test the heat of the piece of steel as it is decreasing, the heat being tested by touching the steel with the end of the stick. When the piece of steel has cooled so that the wood ceases to char, the steel is plunged quickly into soapy water. Very often a piece of steel annealed in this manner will be found to be much softer than if annealed in the regular way by being packed in charcoal and allowed to cool over night.

ANODE. In electroplating, the conductors by which the current enters and leaves the electrolytic bath are known as *electrodes*. The electrode at which the current enters the bath is called the *anode;* that at which the current leaves the bath is called the *cathode*. From this, it follows that the anode is connected to the positive terminal of the current generating source, and the cathode to the negative terminal.

ANTHRACITE COAL. The different kinds of coal all contain carbon, hydrogen, oxygen, and nitrogen, forming a carbonaceous or combustible portion, and also some matter which remains after the combustion in the form of ash. The amount of ash varies considerably in different kinds of coal. *Anthracite* coal contains over 90 and sometimes up to 97 per cent of carbon and has a heating value per pound of combustible of from 14,500 to 15,000 B.T.U. Anthracite is slow to ignite, and burns slowly. It is classified, according to the sizes of the pieces or lumps of the coal as obtained from the mine, into ten different kinds, ranging from "lump" to "culm." The various kinds are as follows: Lump coal, which does not pass through bars set from $3\frac{1}{2}$ to 5 inches apart; steamboat coal, which does not pass through $3\frac{1}{2}$-inch mesh; broken coal, which does not pass through $2\frac{3}{4}$-inch mesh, but passes $3\frac{1}{2}$-inch mesh; egg coal, which does not pass 2-inch mesh, but passes $2\frac{3}{4}$-inch mesh; stove coal, which does not pass $1\frac{3}{8}$-inch mesh, but passes 2-inch mesh; chestnut coal, which does not pass $\frac{3}{4}$-inch mesh, but passes $1\frac{3}{8}$-inch mesh; pea coal, which does not pass $\frac{1}{2}$-inch mesh, but passes $\frac{3}{4}$-inch mesh; buckwheat, which does not pass through $\frac{3}{8}$-inch mesh, but passes $\frac{1}{2}$-inch mesh; rice coal, which does not pass $\frac{3}{16}$-inch mesh, but passes $\frac{3}{8}$-inch mesh; culm or slack of screenings, which passes through $\frac{3}{16}$-inch mesh. For

power plants, pea, buckwheat, rice, and culm coal are generally used, the price of these sizes being considerably less than that of the larger sizes. *Semi-anthracite* coal is similar to anthracite. It contains from 85 to 90 per cent of carbon and has a heating value, per pound of combustible, of from 14,500 to 15,500 B.T.U. It is not as hard as regular anthracite, is less shiny, and burns more rapidly.

ANTI-FATIGUE STEEL. This term is sometimes applied to vanadium steel because of its unusual resistance to continued shocks and vibrating stresses. (See Vanadium Steel.)

ANTI-FREEZING MIXTURES. Anti-freezing mixtures for use in the radiators of gasoline engines are used to lower the freezing point below the lowest atmospheric temperature liable to occur during cold-weather operation. Alcohol and water mixtures have been widely used. Either denatured or wood alcohol may be used. The following figures represent percentages by volume of alcohol in the water and the corresponding freezing temperatures.

Denatured Alcohol. — 20 per cent added to cooling water — freezing temperature, +19 degrees F.; 30 per cent, +10 degrees F.; 40 per cent, −2 degrees F. below zero; 50 per cent, −18 degrees F. below zero.

Wood Alcohol. — 20 per cent added to cooling water — freezing temperature, +10 degrees F.; 30 per cent, −2 degrees F. below zero; 40 per cent, −20 degrees F. below zero; 50 per cent, −40 degrees F. below zero.

Wood alcohol should not be used unless it is definitely known to be free from acetic acid. Owing to the fact that alcohol evaporates much faster than water, the specific gravity of the mixture should be tested occasionally with a hydrometer calibrated for temperature correction. Alcohol lowers the boiling point of water, so that abnormal evaporation may occur, especially on a warm day.

Glycerine Mixtures. — Glycerine raises the boiling point of water and does not evaporate like alcohol, but it is said to be somewhat more injurious to any rubber connections used between the radiator and engine. The freezing temperatures of distilled glycerine and water mixtures are as follows: 20 per cent glycerine (by volume) added to cooling water — freezing temperature, +21 degrees F.; 30 per cent, +12 degrees F.; 40 per cent, zero; 50 per cent, −15 degrees F. below zero.

Ethylene Glycol. — Ethylene glycol, like glycerine, does not evaporate so that the only replacement necessary is to compensate for leaks or mechanical losses. The freezing temperatures are as follows: 20 per cent ethylene glycol (by volume) added to cooling water — freezing temperature, +16 degrees F.; 30 per cent, +3 degrees F.; 40 per cent, −11 degrees F. below zero; 50 per cent −31 degrees F. below zero.

Saline Solutions. — Non-volatile anti-freezing mixtures may be made by dissolving either calcium chloride or magnesium chloride in water. These solutions are less expensive than the alcohol and glycerine solutions, but they are considered inferior due to their tendency to attack metallic parts of the system, especially if there is any solder or aluminum. Two pounds of calcium chloride to 1 gallon of water may be used for temperatures down to 18 degrees F.; 3 pounds per gallon for temperatures down to 1 degree F.; 4 pounds for temperatures down to 17 degrees F. below zero; 5 pounds for temperatures down to 39 degrees F. below zero.

ANTI-FRICTION BEARING METAL. Term applied to any bearing metal of the babbitt-metal class, and specifically to a bearing metal employed by the U. S. Navy Department, composed of 3.7 per cent of refined copper, 88.8 per cent of Banca tin, and 7.5 per cent of regulus of antimony.

ANTI-FRICTION CURVE. Same as Tractrix.

ANTIMONY. Antimony is a silver-white, crystalline, brittle metal of high luster; it is generally found in the mineral *stibnite*, from which it is obtained by first melting this mineral to free it from various foreign matter, and then roasting it to convert it into an oxide. After oxidation, this product is reduced by heating with carbon, metallic antimony thus being obtained. During this heating, loss through volatilization must be prevented by covering the heated mass with a protective layer of potash, soda, or glauber salt. Antimony is permanent in the air at ordinary temperatures but combines with oxygen when heated to a sufficient heat. It readily combines with many other metals, forming alloys that are used to a great extent in the industries. One of the most well-known of these is *type metal*, which is an alloy of lead, antimony, and tin, sometimes containing small percentages of copper and zinc. Antimony in alloys tends to give them hardness, and the property of expanding on solidification. This property is valuable in type casting, because it produces a letter that completely fills the molds.

The atomic weight of antimony is given by two investigators as 120 and 121, and is generally assumed to be 120.2; melting point, 630 degrees C. (1166 degrees F.); boiling point, 1440 degrees C. (2625 degrees F.), but the metal begins to vaporize at about 1300 degrees C. (about 2370 degrees F.); its specific gravity is generally given as 6.71, although it may vary from 6.70 to 6.86; assuming the specific gravity to be 6.71, the weight per cubic inch is 0.2422 and the weight per cubic foot, 418.7 pounds; specific heat, 0.0523; linear expansion per unit length per degree F., 0.00000627; electric conductivity (assuming that of silver to be 100), 3.59.

ANTIQUE BRONZE FINISH. See Bronzing.

ANVIL QUALITY AND WEIGHT. The quality of an anvil can generally be judged by its ring, a good anvil giving out a clear, sharp sound when struck with a hammer. If soft or defective, the sound will be dull. A good anvil so mounted that it gives out a full volume of sound is easier to work upon than one having a dead ring. Anvils ordinarily vary in weight from 150 to 300 pounds. A mistake is often made in selecting anvils that are too light for the service required. A 300-pound anvil is suitable for almost any kind of machine blacksmithing, and, if of this weight or heavier, it will not move around while in use or need to be strapped to its block. The square hole in the face of an anvil for receiving the cutting and forming tools is called the "hardie hole," and the small round hole near it, the "pritchel hole." Anvils are usually made with a wrought-iron body to which is welded a hardened steel face. The U. S. Navy Department specifications for anvils require that these be made from a good quality of cast or wrought iron, steel-faced, or from solid steel. The base of the anvils is to be about 12 inches square. If the anvil is made from cast or wrought iron, the horn is to be of steel, in addition to the top being steel-faced. A blacksmith's anvil should be set in relation to the forge so that the horn will be at the blacksmith's left when he turns around to forge a piece. But if he is a left-handed blacksmith, the horn should be on his right hand.

APERIODIC. This term is sometimes applied to an electrical or other measuring instrument which is said to be "dead beat" or which has an indicating hand that moves to position without excessive oscillations. See Damping.

APOTHECARIES' FLUID MEASURE. 1 U. S. fluid ounce = 8 drachms = 1.805 cubic inch = $\frac{1}{128}$ U. S. gallon; 1 fluid drachm = 60 minims; 1 British fluid ounce = 1.732 cubic inch.

APOTHECARIES' WEIGHT. 1 pound = 12 ounces = 5760 grains; 1 ounce = 8 drachms = 480 grains; 1 drachm = 3 scruples = 60 grains; 1 scruple = 20 grains.

APPARENT POWER. The expression "apparent power" is used in connection with alternating-current circuits, to distinguish it from the true power or energy. It is the product of the mean effective value of the voltage across the circuit multiplied by the mean effective value of the current therein, as read directly from a voltmeter and ammeter. It is expressed in kilovolt-amperes (KVA).

$$\text{Apparent power} = \frac{\text{true power}}{\text{power factor}}.$$

For unity power factor, the apparent power in volt-amperes is equal to the true power, expressed in watts.

APPRENTICE TRAINING PLAN, MILWAUKEE. See Milwaukee Apprentice Training Plan.

APRON. In machine construction, a protecting cover which encloses a mechanism is sometimes called an apron, this term being applied particularly to the apron of a lathe which covers the mechanism employed for transmitting feed motion to the cross-slide and for engaging and disengaging the feed motion of either the cross-slide or the carriage.

AQUA-FORTIS. A term applied especially to a weak grade of nitric acid.

AQUA REGIA. Aqua regia is a mixture composed of three parts of hydrochloric (muriatic) acid and one part of nitric acid; it has a reddish yellow color, and has the peculiar quality of dissolving gold, platinum, and other rare metals which are insoluble in other acids. It is often used as an etching fluid, especially for high-speed steel. It should be used immediately after being prepared or mixed, as it loses its properties even after a short time.

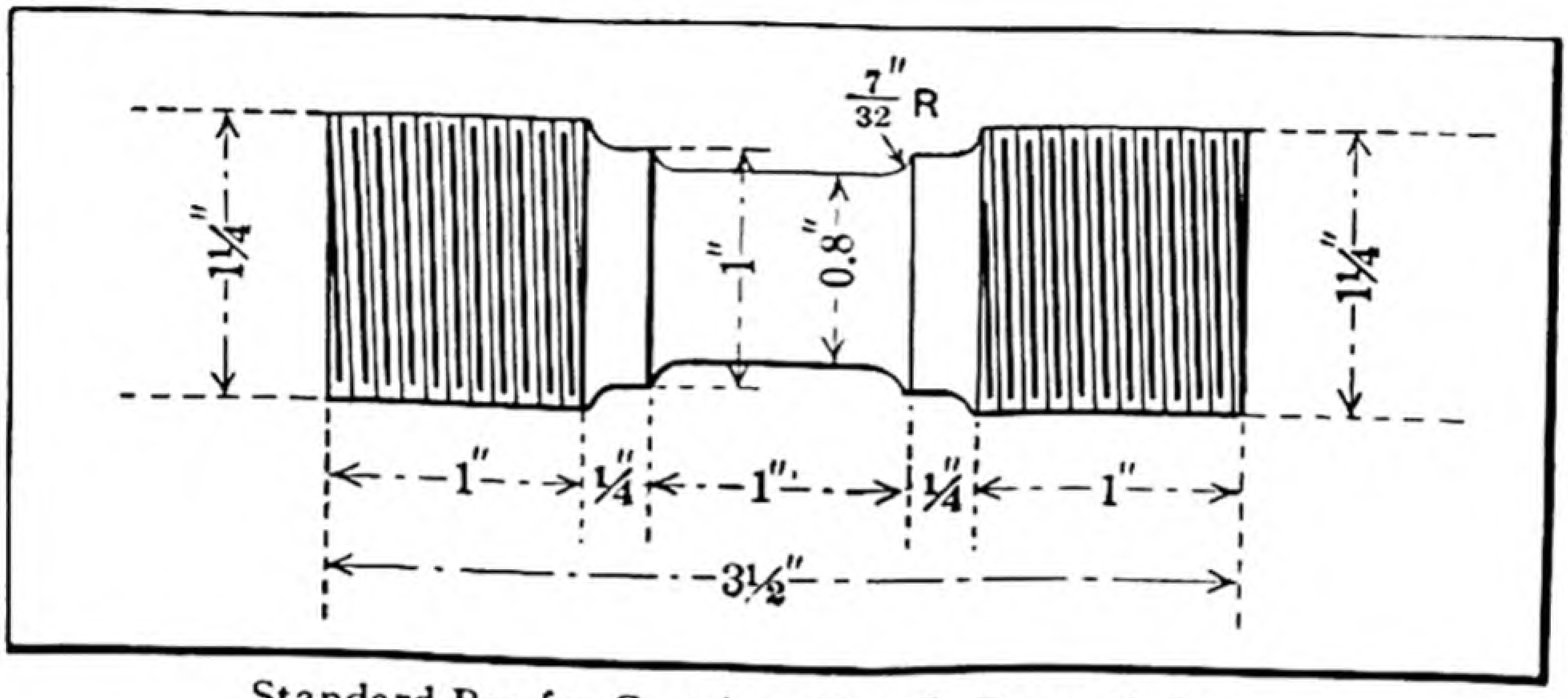
AQUOMETER. An aquometer, more generally known as a *pulsometer*, may be defined as a steam pump which acts partly by direct steam pressure and partly by vacuum. See Pulsometer.

ARBITRATION BAR. According to the methods for the testing of cast iron adopted by the American Society for Testing Materials, the quality of the cast iron is determined by means of an arbitration bar. This bar is $1\frac{1}{2}$ inch in diameter by 15 inches long, and must be cast in a thoroughly dried and cold sand mold. Two sets of bars are cast from each heat; one set from the first and the other from the last iron going into the castings. If the heat exceeds 20 tons, an additional set of two bars is cast for each 20 tons or fraction thereof. If the mixture is changed during the heat, one set of two bars shall be cast for every mixture. The bars must not be tumbled or otherwise treated, but simply brushed off before testing. A transverse test is made on all the bars cast. The supports are placed 12 inches apart; the load is applied in the middle, and the deflection at rupture noted. One bar of every two in a set must fulfill the requirements. The rate of application of the load is from 20 to 40 seconds for a deflection of 0.10 inch.

Three different tests are specified for light, medium, and heavy castings. A light casting is one which has no section over $\frac{1}{2}$ inch thick; a heavy casting is one which has no section less than two inches thick; a medium casting is one which is not included in the classification of light or heavy. The transverse strength of the arbitration bar must not be under 2300 pounds for light, 2900 pounds for medium, and 3300 pounds for heavy castings. The deflection in no case must be less than 0.10 inch.

A tensile test is not recommended by the specifications of the American

Society for Testing Materials for ordinary gray iron castings, but, in case it should be required by a purchaser, the test shall be made on a bar turned from any of the broken pieces from the tranverse test of the arbitration bar to dimensions as indicated in the illustration. The tensile test must show a strength of not less than 18,000 pounds per square inch for light, 21,000 pounds per square inch for medium, and 24,000 pounds per square inch for heavy castings. Borings from the broken pieces of the arbitration bar are used for



Standard Bar for Cast-iron Tensile Strength Tests

sulphur determinations. The sulphur content must not be over 0.08 per cent for light castings, 0.10 per cent for medium castings, and 0.12 per cent for heavy castings. One test for sulphur content must be made for each set of two bars. Unless furnace iron is specified, all gray-iron castings are expected to be made by the cupola process.

ARBOR AND MANDREL. The names *arbor* and *mandrel* are often used interchangeably to designate a shaft or spindle that is employed for holding bored parts while turning the outside surfaces in a lathe. Tools of this class are known as " mandrels " by most small-tool manufacturers, whereas the spindles or supports for milling cutters, saws, etc., are called " arbors." In a great many machine shops and tool-rooms, however, the term arbor is commonly used to indicate a tool or shaft for holding parts while turning, although some forms of work-holding devices are known as mandrels even by those who ordinarily use the name arbor. A cylindrical piece or other form about which a blacksmith sometimes forges a ring or collar is known as a mandrel, and this name is applied to other classes of tools which are never referred to as arbors.

ARBOR PRESS. Arbor presses provide effective means of forcing arbors or mandrels into drilled or bored parts preparatory to turning or grinding operations on the exterior. In using the arbor press, the work is placed on the base with the hole in a vertical position, and the arbor (which

should be oiled slightly) is forced down into it by a ram, operated either by hand or power. Power-driven arbor presses are particularly desirable for large work, owing to the greater pressure required for inserting arbors that are comparatively large in diameter. Arbor presses can also be used for other purposes, such as forcing bushings or pins into or out of holes, bending or straightening parts, or for similar work.

ARC. See Electric Arc.

ARCHIMEDEAN PRINCIPLE. Two of the fundamental principles of mechanics are frequently spoken of as the *Archimedean principles*, because of their having been originated by Archimedes, the Greek mathematician, who lived in the third century B.C. The first of these principles relates to the equilibrium of a lever, laying down the law that equilibrium will exist when the moments of two weights on opposite sides of the fulcrum are equal. The other principle, more frequently known as the *Archimedean law*, relates to hydrostatics, and pronounces the fact that a body immersed in a fluid loses an amount of weight equal to that of the fluid it displaces.

ARCHIMEDEAN SCREW. A device, said to have been invented by Archimedes for raising water, consists principally of a cylinder within which is a shaft with a deep helical thread or groove. The cylinder is placed in an inclined position with its lower end and the screw immersed in water. As the tops of the thread of the screw fit the cylinder closely, water will move upwards through the helical chambers formed by the groove or thread when the screw is revolved. The modern screw conveyer, used for raising other materials, is a form of Archimedean screw.

ARCHINE. A Russian measure of length, equal to 28 inches or 0.711 meter.

ARCH POWER PRESSES. Presses of this class include designs built with a wide bed and arched frame, and a comparatively small slide. Such presses are recommended mainly for large blanking work or shallow forming operations on the lighter gages of metal.

ARCING GROUNDS. Grounds on transmission and cable systems are frequently the cause of interruptions and damages to apparatus. On overhead lines, the arc to ground breaks insulators and burns off the line conductors. On underground cable systems, the arc to ground quickly burns to the other conductors, causing a short circuit. In addition to these troubles, due to the heat of the arc, the rapid make-and-break of the arc sets up high frequency disturbances which are very dangerous to the system and the connected apparatus. It also causes great annoyance by interfering with the operation of parallel telephone lines. The *arcing ground suppres-*

sor removes or minimizes these troubles, short-circuiting and extinguishing the arc by a switch which automatically closes and momentarily grounds the grounded phase at the power station. Its use is limited to non-grounded systems.

ARC LAMPS. The light in arc lamps is produced by two carbon rods which are connected in an electric circuit so that the circuit is closed by the contact of the tips of the carbon rods. When, after such contact, the carbon rods are again separated, the electric circuit is not broken, if the space between the carbons is not made too great, and an arc of light will be formed between the two points. The light emitted is due to the intense heat of the tips of the carbon rods, and also, to a smaller degree, to the arc itself.

When *direct current* is used for arc lighting, most of the light is produced by the end of the upper or positive carbon rod, or electrode, which acquires a hollow center known as the "crater of the arc." This crater, which throws the light downward, has a temperature of from 5500 to 6000 degrees F., a temperature that is high enough to vaporize carbon. The lower or negative carbon rod or electrode becomes pointed at the same time as the positive one is hollowed out. The carbons are consumed by the passage of the current, the positive electrode being reduced in size about twice as fast as the negative electrode.

When an *alternating current* is used for arc lamps, the upper carbon becomes alternately the positive and the negative electrode and, in this case, no crater is formed; but both electrodes become pointed and the two electrodes give off about the same amount of light and are consumed with about the same rapidity. The great illuminating property of the crater in the direct-current arc, however, is lost, and the light given out by the alternating-current arc is thrown upwards as much as downwards, which makes it necessary to use a reflector in order to take advantage of the full effect of the light produced.

ARC-LIGHT ROPE. A wire rope known as *arc-light rope* is made from 9 strands each containing 4 or 7 galvanized wires, and a hemp center. It is used primarily for supporting arc lights, and is made in diameters varying by 16ths from $\frac{1}{4}$ to $\frac{1}{2}$ inch. The $\frac{1}{4}$- and $\frac{5}{16}$-inch sizes are constructed from strands with 4 wires each, while the larger sizes are constructed from strands having 7 wires each. The breaking strength of arc-light rope is 1125 pounds for the $\frac{1}{4}$-inch size, 2200 pounds for the $\frac{3}{8}$-inch size, and 4700 pounds for the $\frac{1}{2}$-inch size. This rope may be used to advantage for all purposes where a rope is exposed to moisture.

ARC OF ACTION. This term, as applied to gearing, is the angular distance a tooth travels from the point where it first makes contact with its mating tooth until it leaves contact (sometimes called angle of action).

Arc of approach is the angular distance from the point where tooth contact begins to the intersection of the point of contact with the pitch line. *Arc of recess* is the angular distance from the intersection of the point of contact with the pitch line to the point where tooth contact ceases.

ARC SINE AND TANGENT. The expressions "arc sine," "arc tangent," "arc cosine," and "arc cotangent," or, as used in their abbreviated forms, "arc sin," "arc tan," "arc cos," and "arc cot," are used to signify the arc or angle which corresponds to a given value of cosine, cotangent, etc. For example, the sine of 40 degrees is 0.6428; then, arc sin 0.6428 = 40 degrees. The expression "arc sin α" is also written "$\sin^{-1} \alpha$." This latter method, while frequently used, is hardly mathematical in its form, because the use of a negative exponent in this manner might easily lead to confusion and be misunderstood for the expression "$(\sin \alpha)^{-1}$," which latter expression means the reciprocal of sin α, or $1 \div \sin \alpha$.

ARC WELDING. The principle involved in arc welding consists chiefly in the heating of the work to be welded to a welding heat by means of an electric arc produced or struck (1) between the part to be welded and a carbon electrode; (2) between the work itself and a metallic electrode. When carbon electrodes are used, a metal rod is nearly always employed for feeding additional material into the joint to be welded. When a metallic electrode is used, this electrode is made from a metal which itself is suitable for feeding into the joint to form the material required to complete the weld. See Electric Welding.

ARC WELDING APPARATUS, AUTOMATIC. The term "automatic arc welder" has been applied to welding apparatus so designed that the wire used in metallic electrode welding is fed mechanically at whatever speed is necessary to maintain a constant arc length and arc voltage. The feeding movement is varied according to the size of the wire and the welding current used, provision being made to obtain the necessary variations. This feeding movement is derived from a small motor which drives the wire-feeding mechanism. This automatic arc welder can be used to advantage in welding long continuous seams on pipes, tanks, boilers, etc., where operation is on a production schedule, and such equipment is also being utilized on railways for building up worn cross heads, guides and wheel flanges.

ARGENTAN. The name "argentan" is sometimes used for an alloy of varying proportions of nickel, copper, and zinc. This alloy is more commonly known as German silver or nickel-silver, the name "argentan" being used only as a trade name for a certain product of this kind.

ARGON. Argon is one of the gaseous chemical elements forming one of the minor constituents of atmospheric air. Its chemical symbol is A; its

atomic weight, 39.9; it becomes liquid at a temperature of -186 degrees C. (-302 degrees F.), and solidifies at a temperature of -189 degrees C. (-308 degrees F.). It forms about 0.94 per cent, by volume, of the atmosphere.

ARITHMETICAL PROGRESSION. An arithmetical progression is a series of numbers in which each consecutive term differs from the preceding one by a fixed amount called the *common difference, d*. Thus, 1, 3, 5, 7, etc., is an arithmetical progression where the difference d is 2. The difference in this case is *added* to the preceding term, and the progression is called *increasing*. In the series 13, 10, 7, 4, etc., the difference is (-3), and the progression is called *decreasing*.

ARMATURE. Two essential parts of all generators and motors are the *field magnet*, which produces the necessary magnetic flux, and the *armature*, on which the conductors are arranged. The armature of a generator is that part of the machine containing the winding in which the electromotive force is generated. For direct-current machines, the armature is generally revolving, while, for alternating-current machinery, it is mostly stationary, this being preferable as it makes it easier to insulate the windings, which is important, especially in high-voltage machines. To prevent eddy-currents, armature cores are constructed of iron or soft-steel disks from 0.014 to 0.020 inch thick, arranged parallel to the lines of force and perpendicular to the axis of rotation. These disks are insulated from one another by varnish, and the slots are punched on the inside periphery for holding the windings.

ARMATURE, MOTOR. The armature of a direct-current motor may be divided into four primary parts: (1) the shaft, which transmits the turning moment to the load; (2) the "armature punchings," which are thin disks of magnetic material assembled on the shaft, insulated from each other to prevent hysteresis losses, held rigidly in the form of a cylinder, and having slots cut around the periphery of this cylinder for the reception of the armature windings; (3) the armature windings composed of the current-carrying windings or bars to receive current from the source of power through the commutator; (4) the commutator which is the current collector made up of many parts of current-carrying copper *segments* which are insulated from each other and into which are connected the armature windings. This commutator collects the current from the source of power by means of brushes, and serves a purpose, practically speaking, opposite to that of the commutator of a direct-current generator. The brush rigging is not properly a part of the armature, but is, nevertheless, a necessary adjunct thereto.

Armature Windings. — All armature windings assembled in slotted cores, no matter what their type, are of two layers only, a top layer and a bottom

layer. There are two main types of armature winding commonly employed, one called the *series* or *wave* winding, the other the *multiple*, *parallel*, or *lap* winding. Where possible, the series winding is preferred. The limitations of the use of the series winding are defined by the horsepower output and the number of poles, because the heavy current and the large number of windings in series per circuit give a bad commutating effect. In general, it is used for motors in all sizes where four poles are employed, including ratings up to, say, 100 H.P. at normal speed. All direct-current railway motors, being of the four-pole type, employ the series winding. The multiple winding is used in places where a series winding cannot be used.

ARMATURE REACTION. The useful magnetic flux in the field of a generator under load is produced by the resultant magnetomotive force of the field-exciting current and of the armature current. *Armature reaction* is the term used to denote the influence of the armature current in modifying the value of the field flux. It is measured in ampere-turns, since it is a magnetomotive force. When the armature current leads the induced electromotive force (E.M.F.) in the armature conductors, the armature magnetomotive force (M.M.F.) assists the field M.M.F. and so strengthens the field. When the armature current lags behind the induced E.M.F., the armature M.M.F. opposes the field M.M.F. and so weakens the field. When the current and the induced E.M.F. are in phase, the two magnetomotive forces neither assist nor oppose each other, and the influence of the armature reaction is only to distort the main field without changing its value. The current in the armature, however, always lags behind the induced E.M.F. by reason of the inductance.

The induced armature E.M.F. is proportional to the flux per pole, and thus, with leading current in the armature, the induced E.M.F. is greater than the open-circuit voltage, and, with lagging current, less than the open-circuit voltage. In the latter case, when load is put on the machine, the field excitation must, therefore, be increased in order to overcome the armature reaction by an amount sufficient to neutralize the armature-demagnetizing magnetomotive force.

ARMOR WIRE. Underground electric cables and submarine cables are usually protected from mechanical abrasion by galvanized steel wire, known as *armor wire*. This is a mild steel wire of uniform diameter, having a tensile strength of about 50,000 pounds per square inch, and an elongation of not less than 10 per cent in 8 inches.

ARMSTRONG JOINT. A two-bolt flanged or lugged connection between pipes for high pressures is known as an Armstrong joint. The ends of the pipe are formed so as to hold properly a *gutta-percha* ring. This form of joint was originally used for cast-iron pipe only. There are various

substitutes for this class of joint, many of which employ rubber in place of gutta-percha, and, in some modifications, more than two bolts are used.

ARSENIC. A chemical element, steel-gray in color, having a metallic luster and being very brittle, the symbol of which is As, and the atomic weight, 75.0. The specific gravity varies from 5.4 to 5.95, and the melting point is 850 degrees C. (about 1560 degrees F.). It is a constituent of certain minerals containing iron, nickel, and cobalt, and is also found in small quantities in nearly all iron pyrites.

ASBESTINE. A material used in paints for protecting iron and steel against corrosion, consisting of a natural silicate of magnesia. When used in paints, it prevents the settling of other pigments, and strengthens the paint film. It grinds in 32 per cent of oil. It also occurs in the form known as *talcose*.

ASBESTOS. Asbestos is a fibrous mineral which is non-combustible and therefore has many uses in the industries for fire protective purposes. The composition of asbestos varies somewhat according to the source from which it is obtained. Analyses made of various grades indicate that it contains about 40 per cent of silica, from 42 to 43 per cent of magnesia, from 1 to 3 per cent of ferrous oxide, from 1 to 2 per cent of alumina, and from 13 to 14 per cent of water. Asbestos was formerly a rare curiosity, but now it is applied to a great variety of uses in industrial arts, and these applications are constantly increasing. Its value in the industries depends not only upon its property of withstanding a high temperature, but also upon its low thermal conductivity, making it an excellent heat-insulating material for boilers and steam pipes. It also partially resists the action of acids, and is used as a filtering material for corrosive liquids. It is made up in a number of different forms, such as yarn, felt, paper, boards, etc., and is employed in many fireproof cements. Asbestos is also used as an electric insulating material, but loses its insulating qualities at about 1800 degrees F., although it will recover these qualities, when cooled. It also loses its mechanical strength at the temperature mentioned, and will melt at about 2400 degrees F. In the form of asbestos paper, its puncturing voltage is about 4000 volts per millimeter (0.039 inch). As a non-conductor of heat, it has been applied to a large extent as an insulating material in electric heating devices of various types.

ASHBERRY METAL. Ashberry metal is a composition consisting of 77.8 per cent of tin; 19.4 per cent of antimony; and 2.8 per cent of copper. It belongs to the class of metals generally known as *Britannia metals*. An alloy of the same composition, except that zinc is substituted for the copper, is also known as ashberry metal.

ASPHALT-BASE OILS. See under Lubricants.

ASPHALTUM. Asphaltum or "asphalt" may be either a natural product or the heavy residuum from petroleum. The latter are known as oil asphalts and are obtained largely from mid-continent, Texas, California and Mexican petroleums. Asphalt is a black non-oxidized bituminous hydrocarbon, ranging from semi-fluid to hard in consistency.

Asphaltum is extensively used for flooring and paving purposes, and is also employed as a preservative coating for iron and steel. It is applied either by dipping the object to be coated into a molten bath of asphaltum, as in the case of water pipe, or by pouring the asphaltum onto the surface to be protected, as in the case of bridge floors. The asphaltum to be used for the protection of iron and steel should be applied at from 300 to 400 degrees F. It should be slightly elastic, when cold, and should not soften appreciably at 100 degrees F. The surface to which it is applied should be dry and hot, and the coating should be of considerable thickness.

Asphaltum is also used in engineering as a component of waterproof cements, and also as a waterproof coating for a number of purposes. Asphalt compositions are also to some extent acid-proof, and are used as cements in pipe lines, tanks, etc., where acids or acid vapors must be resisted. Pure asphalt softens at from 200 to 210 degrees F., and is not recommended in cases where it is subjected to heat or to high stresses. As an electric insulating material, asphalt is used to a great extent, as insulation containing asphalt possesses a high resistance to puncture, in addition to flexibility and mechanical toughness. It is also cheap and is not affected by moisture. It is used for the manufacture of insulating varnishes, for the impregnation of insulating materials in order to make them waterproof, and as an insulating covering for cables. The puncturing voltage varies from 5000 to 15,000 volts per millimeter (0.039 inch).

ASSEMBLY, PROGRESSIVE. See Progressive Assembly.

ASSEMBLY, SELECTIVE. See Selective Assembly.

ATMOSPHERIC CONDENSER. Water is the cooling medium used in practically all steam engine condensing apparatus. Air may be used where water is difficult to get or carry or is costly, but air is much less effective than water and the surface for an equal cooling effect has to be much larger. One form of atmospheric condenser consists of an outer cylindrical shell to which are attached upper and lower tube sheets. This shell is filled with air tubes of 4-inch wrought-iron pipe, which extend about 4 inches above the upper tube sheet. The exhaust steam enters through a special form of distributor near the bottom of the shell and is made to circulate among the tubes by means of baffle plates. Extending above the condenser there is a

flue 50 feet in height. The cooling effect is produced by an upward current of air through the tube which is greatly increased by pumping water into the water-pan above the upper tube sheet. This water trickles downwards through the tubes and into a cistern below the condenser. The upper ends of the tubes are notched so that the water, in passing into them, spreads into thin sheets, thus covering the inside surfaces. The exhaust steam in the shell of the condenser heats the tubes and the films of water, causing the latter to evaporate rapidly, thus saturating the air and causing it to pass swiftly up the tubes carrying with it large quantities of heat taken from the condensing steam. The water of condensation is drawn off through a drain connection in the lower tube sheet; whereas, the air is exhausted from the cylindrical drum by means of a pump connecting with an outlet located just below the upper tube sheet. The air and drain pipes are connected and extend to a vacuum or air pump.

ATMOSPHERIC ENGINE. In one of the early types of steam engine, known as the "atmospheric" engine, the steam was admitted only to the under side of the piston and forced the piston upwards, while the down-stroke was effected by the pressure of the atmosphere, a vacuum having been formed under the piston through the condensation of the steam. The cylinder was placed in a vertical direction. This engine was invented by Papin, in 1695, and was first made a practical success by Newcomen, and, subsequently, greatly improved by Watt, who added a separate condenser and air pump.

ATMOSPHERIC LINE. An atmospheric line is one drawn on an engine "work diagram," parallel to the line of absolute vacuum and at such a distance above it as to represent 14.7 pounds pressure per square inch, according to the scale of the steam engine indicator spring used.

ATMOSPHERIC PRESSURE. The normal atmospheric pressure at sea level is generally assumed to be 14.7 pounds per square inch, which corresponds to 29.92 inches of mercury. Frequently, however, the atmospheric pressure is assumed to be the pressure of a 30-inch vertical column of mercury at 32 degrees F., which corresponds to 14.73 pounds per square inch. In the countries using the metric system, the pressure of an atmosphere equals 760 millimeters of mercury (29.92 inches) at 32 degrees F. This corresponds exactly with a pressure of 14.7 pounds per square inch, and is the value generally used in engineering calculations. The pressure in atmospheres is frequently used as a measure for air, steam, or liquid pressures. For example, a pressure of five atmospheres would equal $5 \times 14.7 = 73.5$ pounds per square inch. In calculations where extreme accuracy is not required, it is often assumed that an atmosphere equals 15 pounds per

square inch. This makes it easier to perform calculations, five atmospheres being then equal to 75 pounds per square inch.

ATOMIC HYDROGEN WELDING. Atomic hydrogen welding is a process by means of which metals can be fused without oxidation, welding being performed in some cases on metals as thin as paper. This method utilizes a stream of hydrogen passed through an arc between two electrodes. Since atomic hydrogen is a powerful reducing agent, it reduces any oxides which might otherwise form on the surface of the metal. Alloys containing chromium, aluminum, silicon, or manganese can be welded without fluxes and without surface oxidation. The welding outfit consists of a single-phase transformer for converting the voltage of a 60-cycle source of power to one suitable for the welding equipment; a variable reactor to provide the proper welding current and voltage for different classes of work; and a welding torch by which the actual welding is performed. The torch consists of a holder supporting two tungsten wire electrodes, the electric conductors connecting these electrodes to the reactor, and the tubing for the hydrogen gas. Each electrode is supported inside a nozzle through which the hydrogen is forced out around the electrode. The present equipment is for operation from 60-cycle single-phase circuits only, and is recommended for use on ordinary metals of less than $\frac{1}{4}$ inch in thickness, or on hitherto unweldable metals of greater thickness.

ATOMIC WEIGHTS. Atoms are too small to have their absolute weights determined; therefore, hydrogen, being the lightest known element, was first taken as a unit, and the atomic weights of all other elements were compared with this. It was supposed that, when the atomic weight of hydrogen was taken as the unit, the atomic weight of oxygen was 16, so that atomic weights, expressed on the basis of the hydrogen atomic weight being equal to 1, would also compare directly with the atomic weight of oxygen, expressed as 16. Later investigations have shown, however, that this ratio between the atomic weights of oxygen and hydrogen is 15.88 to 1. The leading chemical societies of the world, however, decided to retain the value of the atomic weight of oxygen as 16, and the atomic weights based on this standard are known as "international atomic weights." It has been found that the specific heat of an element multiplied by its atomic weight is a constant closely approximating the value 6.25. Upon this fact a method of determining atomic weight has been based, as the atomic weight may be found approximately by dividing 6.25 by the specific heat.

ATOMIZERS FOR FUEL OIL. In a *steam atomizer*, the steam is introduced in a concentric or parallel pipe just ahead of the burner, the oil and steam mixing as they leave the burner tip, which results in a very fine spray and complete combustion. The principal objection to this method is the

high consumption of high-pressure steam, with the consequent loss of heat and water. With ordinary good operation, a consumption of from 5 to 6 per cent of the steam generated can be expected, and in many cases it may run considerably higher. Tests have been made which have shown a consumption as low as 3 per cent. Another objection is that the supply of steam has to be regulated, and, therefore, requires skill in operation.

There are *mechanical burners* which are capable of practically the same efficiency as the steam atomizers, even under natural draft conditions, and they require considerably less auxiliary steam. The oil is preheated with surface heaters before it reaches the pressure pumps, so as to obtain a low viscosity for atomizing; the amount of steam used for heating depends directly upon the viscosity or temperature characteristic of the oil. Another loss of steam is that used in the pump for raising the pressure of the oil up from 50 to 200 pounds, as may be required. The mechanical atomizers require more auxiliary apparatus and necessitate using oil temperatures nearer to the flash point, which introduces a slightly greater risk in case of a leak; but the boiler burner fronts are considered simpler and easier to manipulate, due to the absence of steam control.

AUGER SPEEDS. Auger speeds depend largely upon the condition of the wood in regard to seasoning. For example, with the same wood, say pine, speeds could vary by as much as one-third for samples that were very resinous or not properly seasoned. A hard wood, say mahogany, can be satisfactorily cut at a heavier feed and quicker speed than a soft wood badly seasoned or spongy. With spongy woods, there is often difficulty in clearing the chip or core, and this limits the speed. Again, many woodworking machines have an insufficient range of speeds, and small augers have to be underspeeded to avoid overspeeding the large ones. The following speeds for average woods may be taken as a guide for use with a good quality machine and auger: $\frac{1}{2}$-inch augers 2000 revolutions per minute; $\frac{3}{4}$-inch augers, 1600; 1-inch augers 1300; $1\frac{1}{4}$-inch augers, 1200; $1\frac{1}{2}$-inch, 1100; and 2-inch, 1000.

AUSTENITE. Austenite is the solid solution of iron carbide in steel heated above a temperature of about 1300 degrees F. (about 700 degrees C.). Normally, when the metal cools below this point, austenite divides into *ferrite* and *cementite*, the former being practically pure iron and the latter being iron carbide. The dissolution may be avoided partly by suddenly cooling the steel in water, and completely by adding manganese, nickel, tungsten, or molybdenum. Some of the manganese and nickel steels are manganiferous and niccoliferous austenite. Austenite is non-magnetic; hence, steel heated to the hardening temperature is non-magnetic. Austenite is very malleable, and, at the same time, very hard. As the sudden quenching of iron, as

when hardening high-carbon steel, only partly preserves the austenite, carbon steel is strongly magnetic.

AUTOGENOUS WELDING. The process of fusing and uniting metals by the application of intense heat from a gas flame without compression or hammering is generally known as "autogenous welding." The temperature required is obtained by the combustion of a gas containing carbon or hydrogen, or both, by the aid of oxygen. Acetylene is the gas generally used with oxygen although hydrogen is also employed. The gases are thoroughly mixed in a torch or blowpipe to insure perfect combustion, which takes place at the nozzle or tip. Strictly speaking, electric welding is also a form of autogenous welding, but in practice the term has become limited to the form of welding accomplished by means of the blowpipe. Ordinarily, the weld is formed by fusing-in additional material between the surfaces of the joint, which material is in the form of a rod or wire, and may or may not be of the same composition as the material being welded. The heat of the welding torch is also utilized for the cutting of metals by melting and burning the metal away. The autogenous welding process is used both in the manufacture of articles, the parts of which would otherwise be riveted or joined by other means, and in repair work. In both fields it has proved to be of exceptional value.

AUTOMATIC. The term "automatic" is often used as a noun in the machine-building industry, to indicate any kind of automatic turning machine, especially an automatic screw machine or automatic chucking and turning machine of the turret lathe class. See Automatic Machine Tool Classification.

AUTOMATIC DIES. See Dies for Thread-cutting.

AUTOMATIC ENGINES. Many stationary engines are equipped with valves that are controlled by governors of the shaft or fly-wheel type, the arrangement being such that a practically uniform speed of the engine is maintained automatically by the direct action of the governor upon the valve. For instance, if the engine speed varies, the position of the governor eccentric is changed, which, in turn, causes a change in the position of the valve, thus altering the point of cut-off and either reducing or increasing the speed, depending upon whether it is above or below the normal speed. Engines of this general type are often called "automatic" engines. There are various types of governors for engines of this class, and the valves also vary considerably, some engines having a single slide valve controlled by a shaft governor, whereas others have a main valve provided with an auxiliary "riding" or cut-off valve, which is controlled by the governor. The change in the position of the governor eccentric for varying the valve travel

and point of cut-off is effected in different ways. The eccentric may be shifted by changing the angle between it and the crank, or the eccentricity alone may be changed, or both the angularity and eccentricity may be changed simultaneously. The first two methods are rarely employed with a single valve; in fact, most fly-wheel governors are so arranged that, when the engine speed increases, the angle between the crank and the eccentric, as well as the eccentricity, is changed at the same time.

AUTOMATIC GEAR-CUTTING MACHINES. Machines of the formed-cutter type are commonly known as "automatic" gear-cutting machines because, after the gear blank or blanks are in the cutting position and the machine is properly adjusted, all the gear teeth are cut automatically without further attention on the part of the operator. There are certain other types of gear-cutting machines which also operate automatically, except for the insertion and removal of the work, but the term "automatic" is not used in designating them to the extent that it is applied to spur-gear machines of the formed-cutter type.

The general characteristics of these automatic spur-gear machines include a main spindle for holding and driving the work-holding arbor; a cutter-slide arranged to move parallel with the axis of the work-spindle; a mechanism for feeding the cutter-slide at a suitable rate and returning it to the starting point; and a mechanism for indexing the gear blank after each tooth space is milled.

AUTOMATIC LATHE. The automatic lathe is so designed that all of the tool movements are automatically controlled, although the work must be inserted and removed by an attendant. The original machine in this field is the Fay automatic lathe. This type of machine has a headstock and tailstock for driving and supporting the work, the same as on a standard engine lathe, and, in addition, it is equipped with a carriage and supplementary facing and forming tools that are operated automatically. This machine is used for turning rough forgings which may be held on centers, but its principal use is for work held on an arbor; therefore, it is primarily a second-operation machine, completing work that has previously been chucked and otherwise partly finished on the drill press or turret lathe.

AUTOMATIC MACHINE TOOL CLASSIFICATION. The term "automatic," as applied to various classes of machine tools, does not always have the same meaning, and a machine which one manufacturer classifies as automatic would be considered semi-automatic by another manufacturer. For instance, some machines which are designed to perform a certain cycle of operations, but are not capable of presenting unfinished parts to the tools, may be referred to as automatic machines. While such a machine is automatic or self-moving in that it controls the movements of the cutting tools

through one cycle of operations, the attention of an operator is required, so that such a machine is really only semi-automatic.

There are other types of machines which not only control all the movements of the cutting tools, but are equipped with work-feeding mechanisms so that, when one part has been finished, other duplicate parts may be produced automatically. The operation of such a machine is continuous until it needs to be supplied with raw material, which may either be in the form of bar stock, or separate castings or forgings, when a magazine feeding attachment is used. A machine of this type is automatic in the sense that it repeatedly performs all of the necessary operations, which include ejecting the finished work and presenting a new piece or length of stock to the tool. Thus when a machine is capable of automatically producing duplicate parts repeatedly, it is universally referred to as automatic, whereas, if it simply performs a complete cycle of machining operations, but requires the attention of an operator each time a part is finished, it may be considered automatic by some, and semi-automatic by others. In some cases, a machine of the latter class is termed " automatic," while one that is capable of continuous operation is known as a " fully automatic."

AUTOMATIC SCREW MACHINE. The original field of the automatic screw machine was, as its name implies, the making of screws. This field was quickly enlarged to include the making of all kinds of small nuts, washers, pins, collars, etc., and, at the present time, machines of this class are capable of a great variety of operations, not only on parts which are turned from bar stock, but on separate castings or forgings that are automatically fed to the machine by a special feeding mechanism.

Characteristic features of screw machines in general are means for automatically locating successive tools in the correct working position, the automatic changing of feeds and speeds to secure economical operation, and the presenting of new stock to the tools for a similar series of operations. These various movements, which are entirely automatic, are obtained principally from cams which are rotated at pre-determined speeds, and are so formed and set relative to one another that the parts of the machine which they control all operate at the proper time, and at suitable speeds. There are two general classes of screw machines, one class having a single work-spindle and the other, several work-spindles — usually four, five or six spindles. Each spindle of the multiple-spindle type, holds a bar of stock, and tool-holders feed tools forward to operate on these bars of stock held in the opposing work-spindles. After a tool-holder has concluded its working stroke and returned to the starting position, the work-spindle carrier or head is revolved, bringing each bar of stock to the next tool in rotation. The final tool position provides for a cut-off blade, and a complete piece is

finished and cut off at each indexing. One or more forming slides also operate at the different spindle positions if necessary. With this type of machine, all the cutting tools are working on each feeding stroke, as each has a bar of stock presented to it, whereas, with a single-spindle machine, the various tools of the turret operate successively on a single bar of stock.

The time required to complete a part on a single-spindle machine is equal to the total time necessary for all of the individual operations, which includes the time for withdrawing the tools at the completion of the cut, indexing the turret and presenting the succeeding tools to the work. With a multiple-spindle machine, the total time required to complete a piece is equal to the time necessary for the longest single operation plus the time for the idle movements; in some cases, the time is reduced by dividing the longest operation into two operations.

AUTOMATIC SCREW MACHINE ORIGIN. A great field was opened in machine tool development by the invention of the "automatic turret lathe" by Christopher N. Spencer, who was then connected with the Billings & Spencer Co. The idea of designing an automatic turret lathe or screw machine was suggested to Spencer by another machine which he had invented for turning spools for sewing machines. The action of this automatic turret lathe was controlled by a cam cylinder provided with flat strips adjustable according to the movements required, but this exceedingly important feature was overlooked by the patent attorney. This machine proved so successful for making screws automatically that Spencer severed active relations with Billings & Spencer Co. in 1874 and soon afterward established, with others, the Hartford Machine Screw Co.

AUTOMATIC STOP AND CHECK-VALVES. The general practice in steam power plant design is to use two valves in each steam lead from the boilers — the steam pipe which connects the boiler with the main header. One of these valves should be placed at the steam outlet of the boiler and the other at the main header. The valve placed next to the boiler nozzle should be an "automatic stop and check-valve," so called because it closes automatically when the pressure in the boiler falls below the pressure in the steam main, and opens automatically when the pressure in the boiler exceeds the pressure in the steam main. Automatic stop and check-valves are coming into general use, and, where two or more boilers feed into a common main or header, they are required by law in some countries.

With several boilers feeding into the same main and not properly protected by automatic stop valves, it is evident that, if a tube blows out in any one boiler, the steam from the other boilers will discharge through the main into the damaged boiler and out through the ruptured tube. This sudden rush of steam to the disabled boiler will cause a rapid drop of pressure in the

other boilers, and, as the pressure decreases in the boilers, a large quantity of water will be rapidly converted into steam at the lower pressure, thus causing violent waterhammer; in extreme cases, the result of this condition may even cause an explosion in one or more of the sound boilers. A sudden drop in pressure in a boiler causes water to be lifted over with the steam, and this water, flowing to the engines, may result in wrecking an engine. If a tube should blow out in a boiler that is properly protected by an automatic stop and check-valve, the automatic valve will close when the pressure in the boiler falls below that in the main.

AUTOMATIC THREADING LATHE. The automatic type of threading lathe is especially adapted to threading duplicate parts in quantity, because the movements of the lathe are all automatically controlled after the work is placed in position and the lathe is started. This mechanical control, which governs the forward and return movements of the carriage and the movements of the tool, insures more rapid and continuous operation than would be obtained with an ordinary engine lathe.

AUTOMOBILE POWER AND WEIGHT. An analysis made of the horsepower of automobiles as compared with their weight, showed that the less expensive American cars have a power of from 1.3 to 1.5 horsepower per 100 pounds of weight, cars in the medium-priced class have a power of from 1.7 to 1.9 per 100 pounds of weight, while the highest-priced cars have a power of from 2.1 to 2.2 per 100 pounds of weight. Representative English cars have a power of from 1.2 to 1.3, and representative French cars from 1.3 to 1.6 horsepower per 100 pounds of weight.

AUTO-TRANSFORMERS. An auto-transformer has but one continuous winding which serves as both primary and secondary. The high voltage appears on the low-voltage circuit, and, therefore, the use of an auto-transformer is confined to those cases where this feature is not objectionable. Most of the phase connections used with transformers are also possible with auto-transformers which are used wherever their primary and secondary voltages are near enough in value to make their use permissible. Auto-transformers are very largely used for furnishing reduced starting voltages to synchronous or induction motors and rotary converters.

AVOGADRO'S LAW. A principle in physics which states that equal volumes of all gases having the same temperature and subjected to the same pressure contain the same number of molecules.

AVOIRDUPOIS OR COMMERCIAL WEIGHT. 1 gross or long ton = 2240 pounds; 1 net or short ton = 2000 pounds; 1 pound = 16 ounces = 7000 grains; 1 ounce = 16 drachms = 437.5 grains.

1 ton (of 2240 pounds) = 1.016 metric ton = 1016 kilograms; 1 pound =

0.4536 kilogram = 453.6 grams; 1 ounce avoirdupois = 28.35 grams; 1 ounce troy = 31.103 grams; 1 grain = 0.0648 gram.

The following measures for weight are now seldom used in the United States: 1 hundred-weight = 4 quarters = 112 pounds (1 gross or long ton = 20 hundred-weights); 1 quarter = 28 pounds; 1 stone = 14 pounds; 1 quintal = 100 pounds.

AXIOM. An axiom, in mathematics, is a self-evident general proposition which is accepted as true without a proof. The twelve axioms which are the foundation of geometry, and of the mathematical science in general, are: 1. Quantities which are equal to the same quantity are also equal to one another. 2. If equal quantities are added to equal quantities, the totals are equal. 3. If equal quantities are taken from equal quantities, the remainders are equal. 4. If equal quantities are added to unequal quantities, the totals are unequal. 5. If equal quantities are taken from unequal quantities, the remainders are unequal. 6. Quantities which are double the same quantity are equal to one another. 7. Quantities which are one-half of the same quantity are equal to one another. 8. Geometrical quantities which coincide with one another, that is, which actually fill the same space, are equal to one another. 9. The whole is greater than any of its parts. 10. Two straight lines cannot enclose a space. 11. All right angles are equal to one another. 12. If a straight line intersects two other straight lines, so as to make the two interior angles on the same side of it taken together less than two right angles, then these straight lines, if continually produced, must meet upon the side on which the angles are less than two right angles.

AXIS OF EQUILIBRIUM. In a floating body at rest on the water, a line joining the center of gravity of the body with the center of buoyancy. This line is always vertical. See Buoyancy.

AXLE LATHES. Axle lathes are equipped with two tool carriages, so that both ends of an axle may be turned at the same time. On most lathes of this class, the axle is revolved by a special driving head, which is located in the center of the lathe bed. The axle is gripped in the middle by clamps on the head, and the ends are supported by tailstocks. With this arrangement, the work is rotated on "dead centers" (non-rotating centers), which is desirable, and the ends are accessible for the turning operations. The central driving head is operated through gearing from a shaft which extends along the bed and is rotated through additional gearing at the headstock end, either by a belt pulley or a direct-connected motor.

AXLE OIL. This is a natural black lubricating oil (summer black oil) having a fire test of 500 to 550 degrees F. It is used also as a tempering oil.

BABBITTING MACHINE, CENTRIFUGAL. See Centrifugal Babbitting Machine.

BABBITTING MANDREL. An arbor or rod used when lining bearings with babbitt metal, the mandrel corresponding to the shaft which is to have its bearing in the lining.

BABBITT METAL. Babbitt is the name given to a large variety of white metal alloys used as linings for bearings. The name is derived from that of the inventor, Isaac Babbitt, who, in 1839, obtained a patent for a special type of bearing enclosing a soft metal alloy. The exact composition of the original babbitt metal is not known, but the ingredients were copper, tin, and antimony, in approximately the following proportions: 89.3 per cent tin; 3.6 per cent copper; and 7.1 per cent antimony. This metal possesses great anti-frictional qualities, but the high percentage of tin makes it expensive and has led to the substitution of other metals which are marketed under the name of "babbitt metal." These cheaper grades, when properly made, are superior to the original babbitt metal for some purposes. The composition of babbitt metal should be varied according to the pressure to which it will be subjected and the speed of the rotating member; the size of the bearing and thickness of the babbitt metal lining should also be considered. While it is not necessary to use a different composition for each slight variation, a different grade is preferable when the conditions are radically different.

BABBITT METAL FOR HEAVY PRESSURES. The following composition gives a rather hard babbitt metal which may be used for lining connecting-rod and shaft bearings subjected to heavy pressures. This composition conforms to the S.A.E. standard specification for No. 11 babbitt, and is suitable for die-castings.

Cast Products. — Tin, minimum, 86 per cent; copper, 5 to 6.5 per cent; antimony, 6 to 7.5 per cent; lead, maximum, 0.35 per cent; iron, maximum, 0.08 per cent; arsenic, maximum, 0.10 per cent; bismuth, maximum, 0.08 per cent; zinc and aluminum, none.

Ingots. — Tin, minimum, 87.25 per cent; copper, 5.5 to 6 per cent; antimony, 6.5 to 7 per cent; lead, maximum, 0.35 per cent; iron, maximum, 0.08 per cent; arsenic, maximum, 0.10 per cent; bismuth, maximum, 0.08 per cent; zinc and aluminum, none.

BABBITT METAL FOR LIGHT PRESSURES. A cheap babbitt metal intended for large bearings and light service and which is also suitable for die castings, has the following composition, the figures representing percentages:

Cast Products. — Tin, 4.50 to 5.50; antimony, 9.25 to 10.75; lead, maximum, 86.00; copper, maximum, 0.50; arsenic, maximum, 0.20; zinc and aluminum, none.

Ingots. — Tin, 4.75 to 5.25; antimony, 9.75 to 10.25; lead, maximum, 85.50; copper, maximum, 0.50; arsenic, maximum, 0.20; zinc and aluminum, none.

This is the Society of Automotive Engineers (S.A.E.) specification No. 13. This metal should not be used as a substitute for a babbitt with a high tin content.

BABBITT METAL FOR MEDIUM PRESSURES. A relatively cheap babbitt metal intended for bearings subjected to moderate pressures and one that is also suitable for die castings has the following composition, the figures representing percentages:

Cast Products. — Antimony, 9.50 to 11.50; copper, 2.25 to 3.75; lead, maximum, 26.00; tin, minimum, 59.50; iron, maximum, 0.08; bismuth, maximum, 0.08; zinc and aluminum, none.

Ingots. — Antimony, 10.25 to 10.75; copper, 2.75 to 3.25; lead, maximum, 25.25; tin, minimum, 60.00; iron, maximum, 0.08; bismuth, maximum, 0.08; zinc and aluminum, none.

This is the Society of Automotive Engineers (S.A.E.) standard specification No. 12.

BACK CONE OF BEVEL GEARS. The back cone of a bevel gear is the cone generated by swinging the back cone radius about the axis of the gear. The *back cone radius* is the distance perpendicular to the pitch surface from the pitch line to the axis. (This distance is also called virtual pitch radius.)

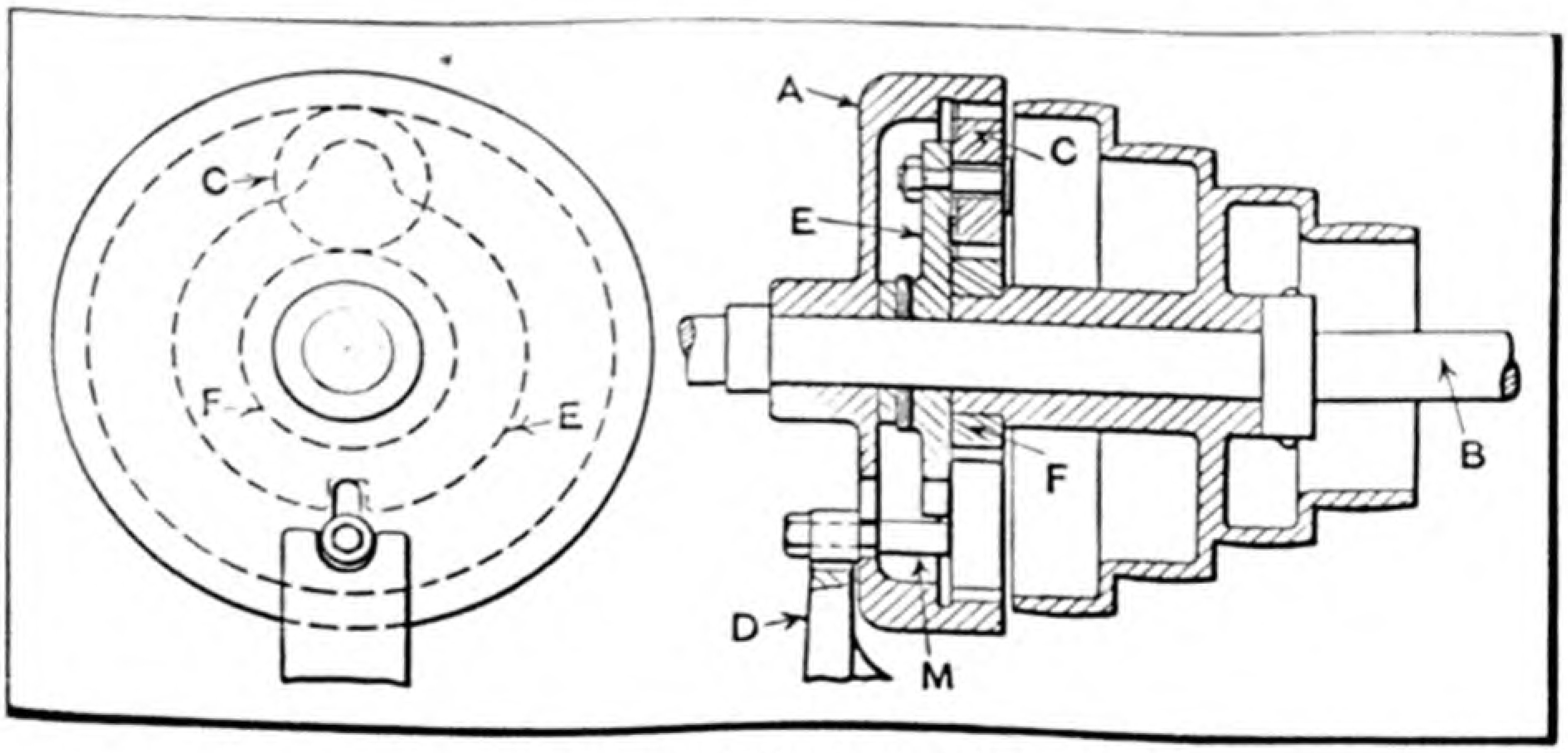
BACK-GEARS. Back-gears are applied to various types of machine tools such as lathes, boring mills, drill presses, etc., in order to increase the range of speeds obtainable with a cone-pulley drive. In the case of an engine lathe, if a slower speed is required than can be obtained with the belt on the largest step of the cone, the latter is disconnected from the spindle, and the back-gears are moved into mesh; the drive is then from the cone-pulley through the back-gears and to the spindle. The fastest speed with the back-gears in mesh is somewhat slower than the slowest speed when driving with the back-gears out of mesh.

Double Back-gearing. — Many lathes have *double back-gears*, so that two ranges of speed may be obtained in addition to those secured by shifting the belt on the cone-pulley. For instance, if there are four steps on the cone-pulley, twelve changes of speed would be available if the lathe were equipped with double back-gears. These gears may be used merely to increase the number of speed changes, or the primary object of including double back-gears in the design of a lathe may be to increase the driving power without sacrificing, appreciably, the number of speed changes, by reducing the num-

ber of steps on the cone-pulley and increasing their width, so that a much wider driving belt may be used.

Triple-geared Headstocks. — That type of gearing for lathe headstocks which has two back-gear shafts, one of which carries a pinion that may be engaged directly with an internal gear on the faceplate, is commonly known as *triple gearing.* This term, however, as used by different lathe manufacturers, is not applied to the same arrangement of gearing, and does not invariably mean that the number of speeds may be tripled.

BACK-GEARS, DIFFERENTIAL TYPE. The planetary form of gearing in which one or more gears not only revolve about their own axes, but turn bodily about a meshing gear, is sometimes applied to speed-changing mechanisms. The illustration shows the application of a planetary gear to the cone-pulley on an upright drilling machine for doubling the range of speeds the same as with ordinary back-gears; this form of mechanism is often called "differential back-gearing." The cone-pulley and the casting *A* are both free to rotate upon the shaft *B*. Gear teeth are cut on the inside of casting



Differential Back-Gearing

A, thus forming an internal gear. The planetary pinion *C* rotates upon a pin fixed in disk *E*, which is keyed to shaft *B*. The gear *F*, about which pinion *C* rotates, is fastened to the hub of the cone-pulley. The pin *M*, which may be clamped in a slot in casting *A*, serves to lock casting *A* and disk *E* together when placed in the upper end of the slot. When the pin is in this upper position, another slot in the disk *E* is engaged by the inner end of the pin. When this pin is lowered into engagement with the stationary arm *D*, casting *A* is held stationary. The speed changes are obtained in the following manner: When the direct drive and the faster range of speeds are required, pin *M* is moved up so as to lock casting *A* and disk *E* together; the shaft and cone-pulley then rotate at the same speed. When the casting *A* is held stationary and disk *E* is free to revolve, the motion is transmitted

through gears F and C to disk E, and the shaft in this way is rotated at a slower speed. In order to secure this reduction of speed by transmitting the motion through the planetary gearing, pin M is lowered into engagement with arm D, thus locking casting A.

BACKING HAMMER. A type of sledge hammer used by blacksmiths for the very lightest work for which a sledge hammer would be required; the backing hammer generally has a ball-peen end like a hand hammer.

BACKING-OFF. See Relieving.

BACKLASH. The lost motion between two machine parts which transmit motion one to the other is often called backlash. This term is applied to lost motion between gear teeth, between cams and their followers, between screws and nuts and other adjacent parts.

BACK PITCH OF RIVETED JOINT. The distance between the center-lines of any two adjacent rows of rivets is sometimes called the "back pitch." This distance, which is measured at right angles to the direction of the joint, should be at least twice the diameter of the rivets for boiler work. Where a single rivet in the inner row comes midway between two rivets in the outer row, the sum of the two diagonal sections of the plate between the inner rivet and the two outer rivets should be at least 20 per cent greater than the section of the plate between the two rivets in the outer row.

BACK PRESSURE. This is the pressure in a steam engine cylinder when the exhaust port is open, and is that against which the piston is forced during the working stroke. The *working pressure* varies throughout the stroke, due to the expansion of the steam, while the back pressure remains practically constant, except for the effect of compression at the end of the stroke. The theoretical back pressure in a non-condensing engine (one exhausting into the atmosphere) is that of the atmosphere, or 14.7 pounds per square inch above a vacuum, but, in actual practice, it is about 2 pounds above atmospheric pressure, or 17 pounds absolute, due to the resistance of exhaust ports and connecting pipes. In the case of a condensing engine (one exhausting into a condenser), the back pressure depends upon the efficiency of the condenser, averaging from 1 to 3 pounds absolute pressure in the best practice.

BACK-REST. Any support employed in machine tools for supporting revolving work, and specifically applied to rear supports for long, slender shafts or similar work while being turned or ground.

BAGASSE AS FUEL. Bagasse is the fibrous portion of the sugar cane left after the juice has been extracted. A pound of bagasse, as it comes from the press, has a heating value of approximately 3400 B.T.U., or about

4.25 pounds are required to equal 1 pound of coal. In burning this fuel with mechanical draft, an air supply of 200 cubic feet of air per pound is required. This gives better results than if burned under a natural draft, as smaller flues and chimney may be employed and a better mixture of the air and gases is secured in this way. An induced draft with the equivalent of from 1 to $1\frac{1}{4}$ ounce pressure seems to give the best results. Under a natural draft, about 270 cubic feet of air are required per pound of fuel.

BAILY'S METAL. Baily's metal is an alloy composed of 82 per cent of copper, 13 per cent of tin, and 5 per cent of zinc, which was used for making the standard imperial yard of Great Britain and the standard yard of the United States in the Bureau of Weights and Measures. It has also been used for making nearly fifty copies of the standard yard supplied by the British government to foreign governments and public institutions.

BAKELITE. Bakelite is a compound made from formaldehyde, carbolic acid, and wood pulp, which are subjected to the necessary conditions of temperature, etc., in order to carry out the chemical process of converting these constituents into a suitable grade of material.

Although bakelite is a component part of many products, such as varnishes, lacquers, enamels, cements, and molded parts, the term is applied by men in the shop chiefly to one of its forms, namely, laminated bakelite. This is the synthetic condensation product, which in the form of laminated sheets, rods, and bars is now in many cases replacing wood, fibre, porcelain, mica, rubber, and metals. It is sold in different grades under different trade names, such as "Formica," "Fibroc," "Textolite," "Dilecto," "Micarta," and "Phenolite."

Bakelite Properties. — Bakelite is an electric insulating material which may be applied either in a liquid or a solid form. In the liquid form, it may be used for impregnating porous materials and as a binding means for various other insulating materials. When in a solid form, it is not affected by water, steam, or oil, and few chemicals have any effect upon it; but it is destroyed at temperatures of about 575 degrees F. It is practically as good an insulator as rubber, but is not as flexible. The puncturing voltage varies from 13,000 to 38,000 volts per millimeter (0.039 inch).

Bakelite is non-hygroscopic, tough, strong, and resilient. It is resistant to heat, cold, acids, chemicals, and oils. As it is chemically inert, it does not deteriorate with age. Being a laboratory product, it is uniform and can be held to a given standard for any particular purpose.

Bakelite is light in weight, and its colors are permanent and will not fade. Its resistance to heat, cold, rain, ice, snow, and salt air make it ideal for electrical insulation. It resists wear well and makes silent contacts when used in moving parts. As a dielectric it does not deteriorate with age. Its

strength permits manufactured parts to be made thin, thus reducing the clearance that might otherwise be required.

Molding materials are usually in finely powdered form and are composed of phenol resinoid, fibrous reinforcing materials, such as wood flour, asbestos, etc., and color pigment. They are fabricated into the finished objects (automotive distributor heads, radio dials, telephone mouthpieces, etc.) by a brief molding operation in steel dies on hydraulic presses. The laminated stock is a dense, uniform material, embodying layers of canvas, linen, or paper, bonded with Bakelite resinoid, and pressed into sheets, tubes, and rods, under the application of heat and high pressure, in hydraulic presses. From these laminated forms finished articles are fabricated by machining rather than molding. Typical finished products include silent gears, radio panels and insulation accessories.

Turning Bakelite. — Bakelite may be set up in the lathe in the same manner as metals, except that reasonable care should be taken in clamping bakelite tubing in a chuck in order to prevent cracking, as it is more brittle than most metals. No lubrication should be used, and whenever possible, bakelite should be turned to size in a single cut. In any case, the finishing cut should remove at least $\frac{1}{8}$ inch of material, because it is more difficult to maintain a uniform diameter when a lighter cut is taken. The material should be turned at a peripheral speed approximately 25 per cent higher than that used for cast iron. It is best to use a wide-nosed tool and employ a coarse feed. The tool should have a large clearance but no rake. It will become dull quickly, and should be sharpened frequently.

Practice in Drilling. — The drilling of bakelite should be done with high-carbon steel drills and without the use of any lubricant. A fast feed should be employed. To insure a clean hole on the under side, it is well to clamp the sheet of bakelite to a wood board at the point where the hole breaks through. If the drill is properly ground, the hole will be true and smooth, but slightly under size. If the hole must be the same size as the drill, the drill should be ground slightly off center.

In order to prevent excessive heating of the drill, it should be withdrawn quickly. Ordinarily a drill can be used for about one-half hour before regrinding is necessary. While an ordinary countersink may be used, a modified drill can be employed to better advantage, as it can be resharpened more easily. The drill should be ground to the proper angle for countersinking and should have very little clearance.

Sawing Bakelite. — Hacksaws may be used for cutting bakelite, the same as any metal. In using band or circular saws, the same speeds as are used for hard woods or fibre should be employed. It is necessary to sharpen and reset the saws frequently when cutting bakelite. When a part must be cut to an exact but irregular outline, from a heavy sheet of bakelite, the pro-

cedure followed in making small metal templets may be used to advantage, in preference to sawing. This consists of scribing the outline on the sheet material, drilling successive holes which are closely spaced just outside the outline, and then breaking out the material between the holes with a wood chisel. The part is then finished to the exact outline with a hand file or a filing machine. On thin material a coping saw can be used. Usually the saw will be good only for cutting one piece.

Punching Bakelite. — Punching is the most difficult of the machining operations performed on bakelite. A plain punch and die may be used on sheets or tubes cut to $\frac{1}{8}$ inch thick, but smooth edges cannot be obtained on a thickness greater than $\frac{1}{16}$ inch. Dies must be kept sharp, and there must be minimum clearance between the punch and die. A little oil can be used on the material or grease can be applied to the punch. To obtain the best results, the material should be heated thoroughly and uniformly in an oven or on a steam table to a temperature of 280 degrees F., preparatory to the punching operation. Sheets over $\frac{1}{8}$ inch in thickness and up to $\frac{3}{8}$ inch should be blanked and then finished in a shaping die. The sheets should be heated and oiled before blanking is attempted.

Threading and Milling. — Threading is a very simple operation, ordinary taps and dies being suitable for this work. For these operations, lubricant can be used in the same way as on metal. In milling bakelite, high speeds and coarse feeds should be used, so that the cutter throws the chips away from the work. If possible, all the material should be removed with one cut. The use of a lubricant is not necessary.

Polishing Bakelite. — Although the original finish on bakelite is a form of varnish, the finish on the machined parts resembles the varnish finish quite closely. If uniformity is particularly desirable, a velvety finish may be obtained by using coarse sandpaper, followed by fine sandpaper and oil.

BALANCED DRAFT. A system of forced mechanical draft employed for boiler furnaces in which a special damper is placed in the smoke outlet from the furnace, this damper being controlled by an automatic regulator operated in connection with the draft fan. This combination maintains a pressure within the furnace equal to that of the surrounding atmosphere and limits the volume of air introduced to that required to effect complete combustion, the draft being balanced by throttling the suction of the chimney in exact proportion to the speed of the blower.

BALANCED SLIDE-VALVE. See under Slide-valve.

BALANCERS. Balancers, also known as "direct-current compensators," consist of a combination of two or more direct-current machines coupled directly to each other, and connected in series across the conductors of a multiple-wire system of electric current distribution. The object of balan-

cers is to maintain the potentials of the intermediate wires of a system, which are connected to the junction points between the machines. When two machines are used, each carries one-half the line voltage; they are then generally employed to provide the neutral of a three-wire lighting system.

BALANCE, STATIC. See Static Balance.

BALANCING. The rotating parts of many machines must be balanced in order to prevent excessive vibrations, especially if the speed of rotation is high. Balancing may be done either by adding a counterbalancing weight or weights to the rotating part, or by removing metal from the heavy or unbalanced side. In the case of reciprocating steam engines, it is the general practice to add a weight opposite the crank in order to counteract, as far as possible, the unbalancing effect of the crank and its connecting-rod. The weight necessary for counterbalancing is calculated by the engine designer in accordance with the various factors involved, and this balancing weight is usually incorporated in the design of the crank, so that it forms an integral part of it. In the construction of fast-running machinery of various kinds, balancing is often necessary because of slight weight variations at different points around the circumference of such parts as flywheels, cylindrical drums, disks, etc. The balancing of such parts involves locating the unbalanced side and either counterbalancing it or removing the excess weight, in order to prevent excessive vibrations at high speed. The excess weight which causes the lack of balance may be very slight, as the vibrations are due to the action of centrifugal force when this unbalanced mass is rotated rapidly. The effect of such vibration may be to injure the entire mechanism of which the rotary member forms a part, and the product of machinery of the manufacturing type is also injuriously affected in many cases. For instance, if the wheel-spindle of a cylindrical grinding machine is out of running balance, the resulting vibrations will cause chatter marks on the work. The importance of balancing fast revolving parts has also been demonstrated in connection with many other types of machine tools as well as other classes of machinery, and balancing of machine parts on a commercial basis has been made possible by the development of balancing machines.

BALANCING MACHINES. Several types of machines have been developed for testing the running or dynamic balance of machine parts. One type which has been used extensively is operated in the following manner. The piece to be balanced is placed in the machine and rotated. At the "critical speed" it sets up a resonant vibration in the pivoted frame work of the machine itself. The amplitude of the vibration is recorded on the dial of the recording amplimeter. The dial reading is then translated by a single manipulation of a calculating rule into terms of ounce-inches, which are the exact equivalent of unbalance.

A counterweight attached to a calibrated disk is next adjusted on its scale so as to provide a counterpoise of the same number of ounce-inches. This counterpoise is now of the right *amount*, but the correct *position* for it is yet to be determined; hence, the part being tested for balance is rotated again and this time the dial reading (interpreted by the calculating rule) indicates the number of degrees by which the counterweight fails to be in the correct angular position. The calibrated disk is next revolved a corresponding number of degrees, and complete counterpoise is thus established. The heavy side of the piece being tested is now precisely in line with the counterweight.

Some balancing machines are designed primarily for wheels, disks and comparatively narrow face parts, whereas others are arranged to test various classes of work, such as crankshafts, rotors of generators and motors, pulleys, spindles, etc. Balancing machines are widely used by motor car manufacturers for testing the crankshafts, and they are also used in other fields for testing various parts, particularly when rotative speeds are high and the requirements are exacting in regard to vibration.

BALANCING MACHINE, SLOW-SPEED TYPE. One type of balancing machine is so designed that unbalanced forces may be detected while the part being tested is revolving much below the critical speed. Light work is revolved at only 260 revolutions per minute, and heavier parts at a speed of approximately 130 revolutions per minute. The amount and location of both static and dynamic unbalance can be determined at both ends of a part with one setting of the work in the machine. By observing electric sparks produced on a dial as an unbalanced part is revolved, the operator can tell whether the part is out of balance statically, dynamically, or in both ways. The angular planes of unbalanced forces are also determined from this dial, while the amounts of unbalance are shown by the graduated dials of handwheels which are turned until the unbalance has been compensated for by shifting weights to change the center of gravity of the work and the standards which support it. The amounts of unbalance are read in ounce-inches or fractions of ounce-inches from the handwheel dials.

BALANCING METHODS. There are two general methods of balancing: 1. *Static* or *standing balance*. 2. *Running* or *dynamic balance*. If a circular part, such as a cylindrical drum or pulley, were mounted in bearings in which friction was practically eliminated, and with the axle in a horizontal position, it is evident that if one side were even slightly heavier than the other this unbalanced side would be at the bottom or lowest point possible when the drum or pulley came to a state of rest. If this same part were brought to such a state of balance that it would remian standing when turned about its axis to any position, it would be in *standing* or *static* balance;

it does not necessarily follow, however, that this part would be in a balanced state when revolving, although if it has a running balance it will also be balanced statically.

If the rotating part is in the form of a thin disk, static balancing, if carefully done, might be accurate enough for high speeds, but if the rotating part is long in proportion to its diameter, and the unbalanced portions are at opposite ends or in different planes, the balancing must be done so as to counteract the centrifugal force of these heavy parts when they are rotating rapidly. This is known as a *running* balance or *dynamic* balancing. Theoretically, to obtain a perfect running balance, the exact position of the heavy sections should be located and the balancing effected either by reducing their weight or by adding counterweights opposite each section and in the same plane at the proper radius; but, if the rotating part is rigidly mounted on a stiff shaft, a running balance that is sufficiently accurate for practical purposes can be obtained by means of comparatively few counterbalancing weights located with reference to the unbalanced parts.

BALL BEARINGS. Ball bearings are designed to provide rolling contact between a rotating shaft or other part, and its supporting members, instead of sliding contact as with plain bearings. Ball bearings are used in preference to sliding bearings principally for the following reasons: There is less loss of power on account of the lower coefficient of friction; the friction of a ball bearing is independent of the viscosity of the lubricant or its temperature; the frictional resistance at starting is very much less than in a sliding bearing; ball bearings are much shorter and more compact than sliding bearings; the scraping and fitting of bearing linings is not necessary; the danger of heated bearings is practically eliminated; a bearing of proper construction can adjust itself to deflections of the shaft; the wear is practically negligible.

Ball bearings may be divided into two main types: *radial* bearings and *thrust* bearings. The former are designed primarily for loads at right angles to the shaft axis, and the latter for axial loads. All radial bearings, however, will withstand thrust loads, and those properly designed for angular contact may resist thrust loads which are equal to or greater than the radial load.

Angle of Contact and Thrust Capacity. — Figuring the capacity of a ball bearing under combined loads is complicated as it is a function of the maximum safe ball load, the angles of contact and of load application, as measured from the plane of the balls, and also the center angle between the balls. As the pure thrust capacity of the bearing is increased by enlarging the angle of contact, there is a reduction in pure radial capacity. For example, a bearing having an angle of contact of 10 degrees will carry, as thrust, 77 per cent of its radial capacity, whereas its radial capacity is reduced 1.5 per cent. Again, a bearing having an angle of contact of 30 degrees will carry, as pure

thrust, 252 per cent of its radial capacity, and has a loss of 13.4 per cent in radial rating.

Any ball bearing under combined loads becomes an angular contact bearing. This angle of contact can either be incorporated in the design or obtained by deformation of the parts under load. In other words, what is known as an annular bearing becomes an angular contact bearing when thrust is applied. Under pure radial load, the contact between the balls and races is in line with the applied load and at right angles to the shaft, but as soon as thrust load is applied, the contact becomes angular and is caused by motion between the inner and outer races until the material is deformed sufficiently to resist the load.

Percentages of Radial and Thrust Loads. — There are three types of bearings that are combined load carriers: First, the annular ball bearing, which is primarily designed for radial loads and has no angle of contact incorporated in its design, therefore having minimum thrust capacity (approximately 20 per cent of its radial capacity). Second, the one-direction angular contact bearing, which has a thrust capacity depending upon race design and the angle incorporated, which is generally made so that the thrust capacity is 100 per cent of the radial capacity. (This bearing, however, when used for combined loads, can only be used in pairs, and must have a threaded or shim adjustment incorporated in the mounting design to allow for initial adjustment.) Third, the double angular type bearing which is really two of the previously mentioned bearings built as a self-contained unit. The functioning of this bearing is not dependent on any exterior adjustment, and the angle of contact is generally such that it will sustain approximately 150 per cent of its radial capacity as thrust.

BALL BEARINGS, LUBRICANTS. See under Lubricants, Applications.

BALL BEARINGS, MOUNTING. If the bearing is to carry a radial load without thrust, the inner race should have a light driving fit on the shaft and be securely clamped against a shoulder by a nut or clamping device which is proof against jarring loose. The outer race of a bearing subjected to a radial load only should fit closely in its retaining box or housing, but be free to "float" or shift in an endwise direction. When the outer race is mounted in this way, it will align itself with reference to the inner race and will tend to have a slow intermittent creeping movement, insuring a proper distribution of the load over the entire surface of the outer race.

If there are several radial bearings on the same shaft, the end-thrust in both directions should be taken by the same bearing, and the outer races of the other bearings should be free to locate themselves. It is considered good practice, when two bearings are mounted on one shaft, to prevent axial thrust by making the inner race of each bearing a light driving fit on the

shaft. The outer race of one bearing has a sliding fit in its seat and is given a slight amount of axial play (say, from 0.010 to 0.020 inch); the outer race of the other bearing is also made a sliding fit, but is allowed considerable axial play. The first bearing takes the radial load and end-thrust, and the second bearing, a radial load only.

BALL-BURNISHING PROCESS. Burnishing, according to one meaning of the word, consists in finishing the surfaces of work by rubbing with a highly polished steel hand tool, which hardens and polishes the surface metal. The ball-burnishing process produces the same effect, but in an entirely different manner, employing quantities of hardened and polished steel balls which are caused to roll over the work while under pressure. This pressure is effected by the weight of the balls which are confined within a tumbling barrel. Each ball thus acts as an individual burnishing tool, and as it rolls over the work, pressed by the mass of balls and work above, it leaves a burnished path on the work.

To burnish a quantity of work, the work and balls are placed in the barrel, water is then added until the contents of the barrel are covered. In this water, about four ounces of burnishing soap chips have previously been dissolved. The handhole covers are then clamped in place, and the mixture tumbled from one to five hours, depending upon the character of the work, metal, etc. The speed ordinarily employed for tumbling ranges from 10 to 30 revolutions per minute, the usual speed being 15 revolutions per minute. After the work has been burnished sufficiently, it is separated from the balls by dumping the mixture into a screen of sufficiently coarse mesh to allow the balls to drop through.

Instead of steel balls, small round steel punchings that are ordinarily a scrap by-product when holes are punched in steel articles, may be employed in the tumbling barrels. These steel punchings are first tumbled with no work in place, and then, after the corners are well rounded, the work is put into the tumbling barrel. It is claimed that the burnishing effect is almost as good as that obtained when hardened steel balls are used, while the cost of the punchings is almost negligible.

BALL CLASSIFICATION. Ball-bearing balls are graded in four main classes, known as "alloy," and A, B, and C grades. Alloy steel balls have the greatest crushing strength and do not vary in size more than 0.0001 inch. Balls classified as A-grade are made from high-grade tool steel and do not vary over 0.001 inch above or below the exact dimension. Balls known as B-grade are the seconds taken from the two higher grades mentioned, and do not vary more than 0.002 inch above or below the exact dimension. The C grade, commonly known as hardware balls, are those picked from the higher grades when these show a defective surface. They may or may not

be as accurate as to size as the other grades, according to the use to which they are to be put.

BALLENTINE HARDNESS TEST. In the Ballentine hardness testing method, a hammer of specified weight is permitted to fall through a specified height on an anvil to which is connected a pin which rests on the specimen to be tested. Instead of measuring the indentation in the material tested, as in the Brinell hardness testing method, the resistance encountered is measured instead. This resistance is measured by the blow of the hammer being transmitted to the test pin through a soft metal recording disk located at the lower end of the hammer, which will be indented to a depth varying in proportion to the resistance the pin encounters in indenting the material to be tested. The recording disk is usually made from lead.

BAND SAW. This term is commonly applied to a machine consisting principally of a band saw in the shape of a flexible ribbon passing over two large pulleys, similarly to a belt, and a table through which the saw passes and upon which the work to be sawed is laid. Band saws are used for cutting wood, especially along curved or irregular lines. Some machines of the band-saw type are also intended primarily for cutting metal.

BAND SAWS FOR METAL CUTTING. The band saws used for cutting-off bar stock and for other metal-cutting operations are similar to the band saws used in wood-working, in that the saw is in the form of a continuous band or belt which passes over revolving pulleys. The metal-cutting band saws, however, are equipped with some kind of mechanism for feeding the saw, and the driving mechanism is so arranged that the return side of the saw will clear a long bar stock. One design of metal-cutting band saw is so arranged that the saw runs in a horizontal direction, the axes of the two saw pulleys being located in a horizontal plane.

BAND-SAW SPEEDS. Band-saw speeds for cutting wood vary from about 4700 feet per minute to 10,000 feet per minute, according to the conditions under which the saw is used. Small band saws — that is, those 2 inches and smaller — are used at a linear speed of about 4700 feet per minute. These saws are usually run over wheels about three feet in diameter, at a speed of 500 R.P.M. For larger band saws, the speeds depend mainly upon the kind of wood being sawed. For seasoned hard wood and for unseasoned, exceedingly hard wood, a saw speed of 7000 feet per minute is recommended. Such exceedingly hard wood would be frozen maple, for example, which is cut extensively in the mills of northern Wisconsin and Michigan. For seasoned, comparatively hard wood and unseasoned hard wood, such as maple, hickory, etc., a speed of 8000 feet per minute is recommended. For seasoned soft wood and unseasoned, comparatively hard

wood, such as oak, a speed of 9000 feet per minute is recommended. For cutting the softest materials, such as unseasoned pine, bass wood, etc., a maximum speed of 10,000 feet per minute is recommended.

BARFF PROCESS. A method for producing a magnetic oxide on iron or steel, in order to protect it from the corrosive effects of air and moisture. See Bower-Barff Process.

BARIUM. Barium is one of the metallic chemical elements, the chemical symbol of which is Ba. Its atomic weight is 137.4. The specific gravity of barium is 3.75; its melting point, 850 degrees C. (1562 degrees F.); and its electric conductivity (silver = 100), 30.61. Barium, as a metal, is expensive. The various salts formed by barium, however, are inexpensive. It occurs chiefly in the form of barytes, or heavy spar, and witherite. It is a metal difficult to obtain in pure form. The metal possesses a silver-white luster, but is very easily oxidized on exposure. It is slightly harder than lead. One of the most important uses is in the barium salts, which are frequently used for heating baths for metals to be hardened. Barium chloride ($BaCl_2 + 2\ H_2O$) is especially valuable for this purpose.

BARIUM CARBONATE. A carburizing material frequently used in combination with wood charcoal for increasing the carbon content of the surface of low-carbon steel, so that the steel may be casehardened. A carburizing mixture frequently used contains 40 to 60 per cent, by weight, of barium carbonate, the remainder being wood charcoal.

BARIUM-CHLORIDE HEATING BATHS. High-speed steel requires to be heated to a much higher temperature for hardening than does ordinary carbon steel. While a heat of from 1400 to 1600 degrees F. is sufficient for tools made from carbon steel, a heat of from, at least, 1800 to 2200 degrees F. is required in order to satisfactorily harden high-speed steel tools. The ordinary lead bath commonly used for heating carbon steel tools cannot be used at such high temperatures as these, and as it is, in general, unsatisfactory to heat the tools in an oven furnace, owing to the difficulty of correctly determining the hardening temperature when the tools are heated in this way, some heating medium has been sought which could stand high temperatures and in which the pieces to be hardened could be immersed so as to obtain a uniform heat without danger of burning delicate points or cutting edges — a danger which is always present when high-speed steel tools are heated to a high temperature in an open heating furnace. A temperature up to 2200 degrees F., and even higher, can be obtained by the barium-chloride bath.

The hardening of high-speed steel in barium-chloride electrically heated baths has not always been satisfactory. In one series of experiments the results were good when the salt bath was new, but it appeared that the

chemical composition of the salt bath in the electric furnace gradually changed, producing a soft surface on the steel which was quite noticeable when the salt bath had been in use for about a week. This softness of the surface was noticeable directly after the hardening, and not merely after the temper had been drawn. A certain sediment collected in the electric salt bath, and the color of the barium chloride became darker. The same barium chloride melted in an ordinary graphite crucible retained its lighter color, and even after two full weeks' use, the hardening results were satisfactory. The amount of barium chloride used in the electric furnace was much greater than that required for doing the same amount of work in a graphite crucible.

Experiments made later in Sweden indicate that it is possible to obtain perfectly satisfactory results by hardening high-speed steel in electric barium-chloride baths. If silica brick or clay is used for the crucible, it will be found that there is no chemical action and that high-speed steel can be hardened without any soft spots on the surface. The risk of breakages in hardening also appears to be diminished, when there are no soft spots on the surface. The objectionable results, therefore, in the early experiments are almost certain to have been due to the character of the lining of the crucible and the chemical action of the electrically heated salt bath on this lining. When the proper kind of crucible is used, it appears that properly conducted hardening of high-speed steel in electrically heated salt baths cannot be surpassed by any other hardening method, as regards either the accuracy with which the temperature can be obtained and maintained, the hardness of the surface, or the freedom from hardening cracks.

BARIUM CHROMATE. A material used in paints for protecting iron and steel against corrosion; it is pale yellow in color and made by treating barium chloride with sodium chromate. On account of the impurities generally contained, its protective value is not very high.

BARIUM SULPHATE. A material found in large quantities in nature, extensively used in paints for the protection of iron and steel against corrosion. It grinds in 10 per cent of oil. An artificial form known as *blanc fixe* may be made by precipitating a barium salt by a soluble sulphate. Both the natural and artificial product may contain acids, and should be tested for this before being used as a protective paint.

BARLOW'S FORMULA. One of the most commonly used formulas for calculating the strength of cylinders subjected to internal pressure is known as the *Barlow formula*, and is as follows:

$$t = \frac{DP}{2S},$$

in which t = thickness in inches; D = outside diameter in inches; P = pressure in pounds per square inch; S = allowable tensile stress in pounds per square inch.

BAROGRAPH. A form of *barometer* for measuring the pressure of the atmosphere, which does not employ mercury or other liquids as does the ordinary barometer. Other forms of a barometer of this class are aneroids and baroscopes.

BAROMETER. The barometer is an instrument for measuring the pressure of the atmosphere. In its simplest form it consists of a tube about 36 inches long, hermetically closed and having a vacuum at the upper end, and containing mercury. Two types of this form of barometer are made. In the *cistern* barometer, the tube is placed with its open lower end in a vessel containing mercury, the pressure of the atmosphere being measured by the difference of the height of the mercury in the tube and in the cistern. In the *siphon* barometer, the tube is bent at its lower end into a U-shape. The pressure of the atmosphere is read off as the difference of the levels of the mercury in the two vertical tubes of the U. Various forms of barometers which do not employ mercury or other liquids are also made, known as *aneroids*, *baroscopes*, *barographs*, etc. Normal atmospheric pressure is assumed to exist when the difference between the two levels of mercury in the barometer is 29.92 inches (760 millimeters).

BAROMETRIC AEROMETER. An instrument for ascertaining the specific gravity of liquids, consisting of a vertical U-tube, with open ends, mounted upon a stand. The method in which it is used is as follows: Water is poured into one branch of the tube and the oil or liquid the specific gravity of which is to be measured is poured into the other. The vertical parts of the tube are provided with graduations and the relative height of the water in the one leg of the U, and the liquid in the other, indicates the specific gravity. See Aerometer.

BAROMETRIC CONDENSER. A barometric condenser which is also known as siphon condenser, is a device for condensing the exhaust steam from engines or turbines, by mixing the exhaust steam directly with the condensing water. This type of condenser is well adapted to plants in which the condensing water is suitable for being fed directly to the boilers and also for plants where only the condensation of the steam is desired and where the water of condensation is not used again.

BAROSCOPE. A form of *barometer* for measuring the pressure of the atmosphere, which does not employ mercury or other liquids as does the ordinary barometer.

BARREL CONVERTER. A converter similar to a Bessemer converter, used in the refining of copper by the *Manhès process*.

BARYTE. A barium sulphate used in paints for protecting iron and steel against corrosion; see Barium Sulphate.

BARYTES CEMENT. An acid-proof cementing material composed of pure, finely ground sulphate of barium made into a putty with a solution of silicate of soda. This solution sets very hard when heated and is then proof against acids. The specific gravity of the silicate of soda should be between 1.2 and 1.4, or from 24 to 42 degrees Baumé; if too thin, the cement will not hold; if too thick, it will expand and break.

BASE IN CHEMISTRY. A chemical base is a compound which will react with acids to form salts. It generally consists of a combination of a metal with oxygen. All bases that dissolve in water are known as *alkalies*.

BASE CIRCLE OF A GEAR. There are various curves which might be applied to gear teeth in order to secure rotation between two gears having intermeshing teeth, but the involute curve is used almost universally because it has certain practical advantages. If a circular disk were placed upon a drawing-board, an involute curve would be described by the end of a taut line when the latter was unwound from this disk. The disk represents what is known as the *base circle*, because it is from this circle that the involute is derived. The base circle must always be smaller than the pitch circle, in order to obtain involute tooth curves which meet practical requirements. A tooth curve cannot extend below the base circle from which it is derived.

The ratio of gearing depends upon the diameters of the pitch circles, the sizes of which are proportional to the numbers of teeth in the pinion and gear. The base circles must also be proportioned according to the same ratio. For example, if the *pitch diameter* of a gear or the diameter of its pitch circle is four times that of the pinion, the base circle of the gear must also be four times as large as that of the pinion base circle. The diameters of these base circles may be changed, but they must always remain proportional to the velocity ratio the same as the pitch circle diameters.

BASIC BESSEMER PROCESS. See Bessemer Process.

BASIC DIMENSION. The basic size of a screw thread or machine part is the theoretical or nominal standard size from which variations are made, as in the case of fitted parts which must have an allowance for providing a certain class of fit. The use of the hole diameter as the basic diameter has practical advantages in obtaining different classes of fits, especially when it is economical to finish holes by means of standard tools. For example, assume that holes are to be finished by reaming, and that shafts or plugs are to be fitted

into them, this being a common condition in connection with various machine-building operations. If the diameter of the hole is basic, its size, within a small tolerance, may be maintained readily by the use of proper reaming equipment, and the diameter of a shaft or plug may be varied much more readily than that of the hole, in order to obtain the allowance for whatever class of fit is desired; therefore, different kinds of fits in holes finished by the same reamer may be obtained merely by grinding the shaft or plug to a diameter which gives the proper fit allowance. In the case of threaded holes, the tap is usually solid or non-adjustable, whereas dies ordinarily may be adjusted readily to obtain different classes of fits.

As both the hole and shaft or plug would ordinarily be given a certain tolerance, the basic dimension of a hole (except for forced fits) should be the minimum limit or diameter, there being a plus tolerance, and the nominal dimension of a shaft or plug should represent the maximum limit or diameter, there being a minus tolerance. The advantage of this method is that the minimum clearance between hole and shaft, or the " danger zone," is indicated by a direct comparison of the basic hole diameter and the nominal shaft diameter; the direction of the tolerances is such as to increase this clearance. For a forced fit, the basic hole size is the maximum diameter, the tolerance being minus, and the nominal shaft size is the minimum diameter, the tolerance being plus; consequently, the minimum fit allowance or interference between hole and shaft (or the " danger zone " for a forced fit) is indicated by a comparison of the basic hole diameter and the nominal shaft diameter. In this case the direction of the tolerances increases the interference or forced fit allowance.

When it is economical to use cold-drawn or other commercial stock without machining then the maximum shaft size should be basic.

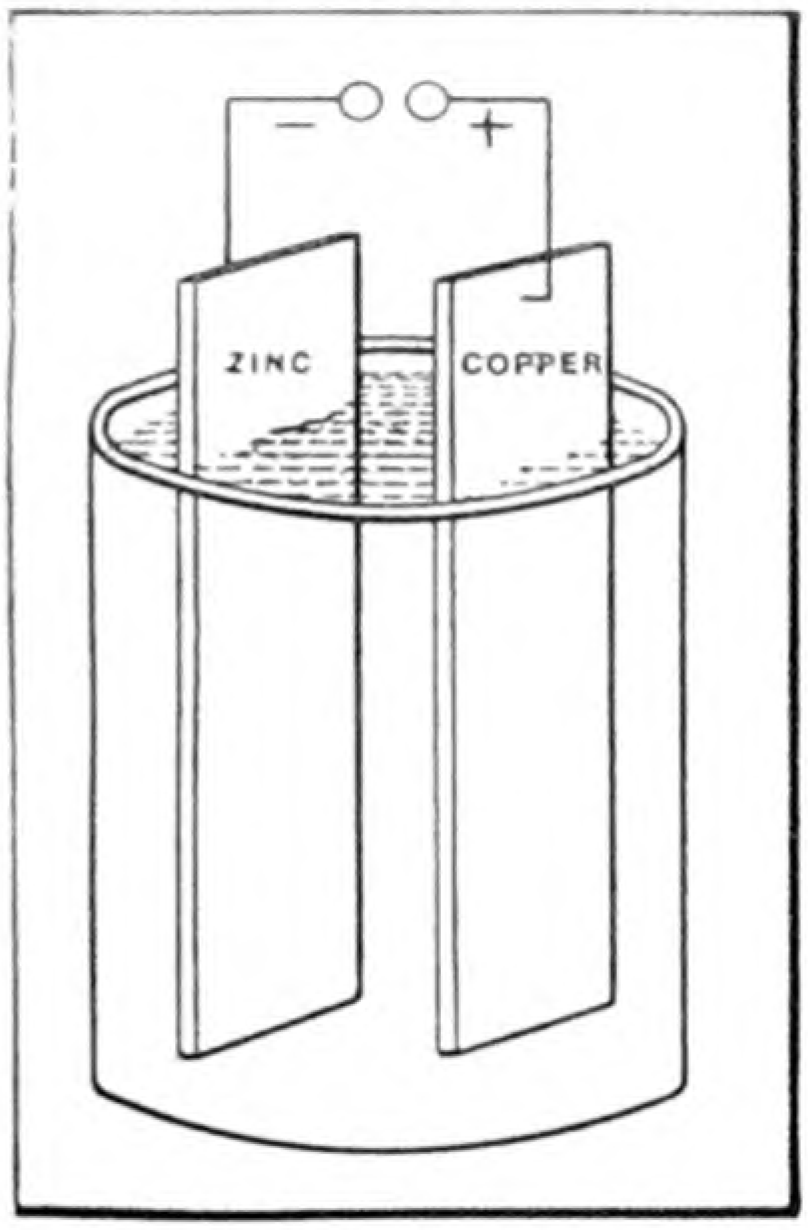
BASIC FIREBRICK. A firebrick in which alumina predominates.

BASIC PIG IRON. A term applied to pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process (restricted to pig iron containing not more than 1.00 per cent of silicon).

BASIC SALT. In chemistry, a basic salt is formed when all the hydrogen has been removed from an acid and yet some of the base remains.

BATTERIES. The apparatus for transforming chemical energy into electric energy is known as a *primary cell*. Two or more of these cells joined together form a *primary battery*, although the term " battery " is frequently applied to the single cell as well. A primary cell consists of a liquid, known as the *electrolyte*, and two metals called the *elements* or *electrodes*. The action of the primary cell depends on the decomposition of the electrolyte, and

the effect of the parts of the liquid on the electrodes. That electrode on which the electrolyte acts the more vigorously is termed the *positive*, or *anode*, and is indicated by a + sign; the other is termed the *negative*, or *cathode*, and is indicated by a − sign; but the positive *pole*, or *terminal*, of a cell is joined to the negative electrode, and the negative pole of the cell is joined to the positive electrode.



Simple Voltaic Battery

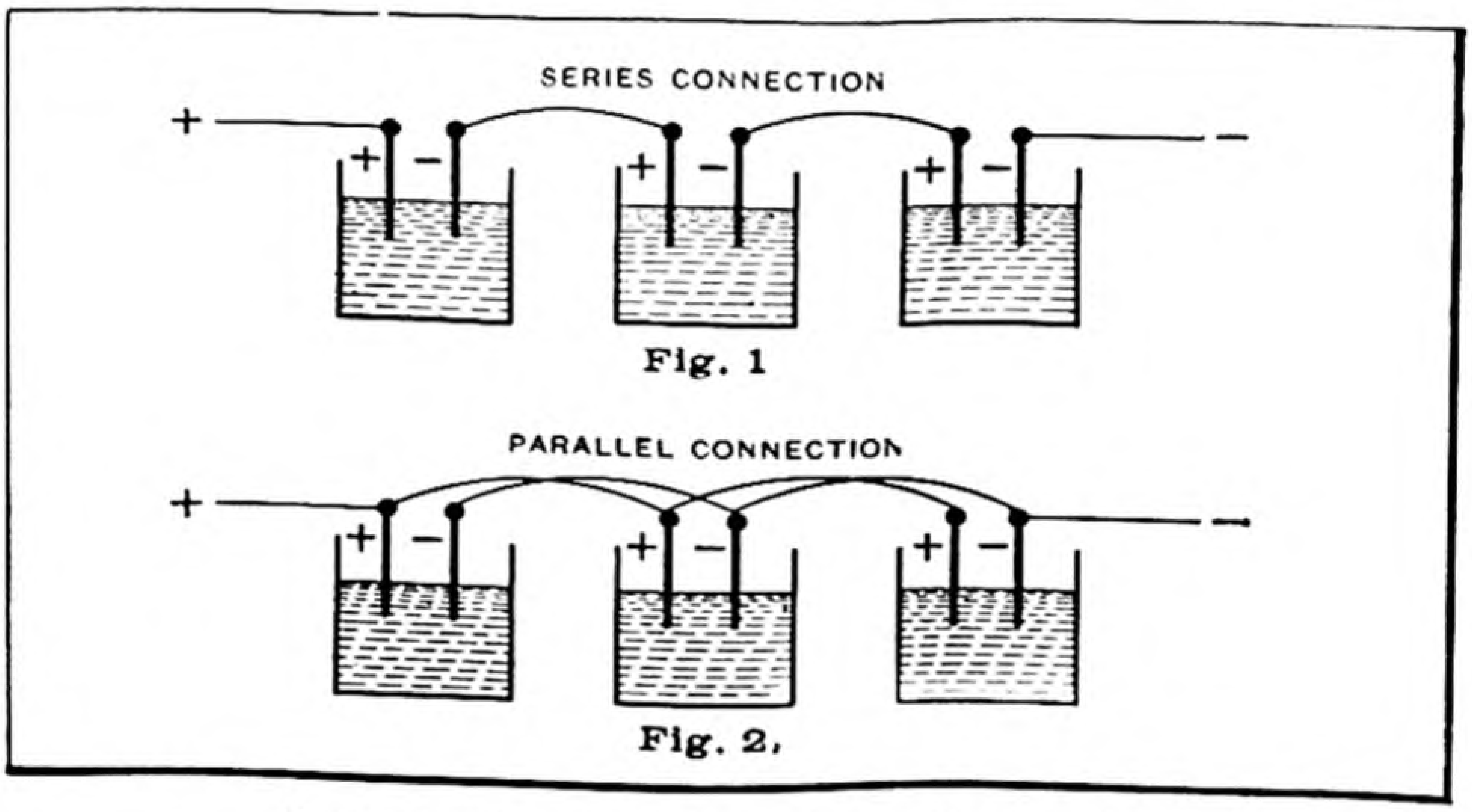
In the simple voltaic cell, shown in the illustration, dilute sulphuric acid (H_2SO_4) is used as the electrolyte and copper and zinc strips as the electrodes. When these electrodes are connected externally, the radical SO_4 of the sulphuric acid, which has a greater affinity for zinc than for copper, combines with the zinc, and the hydrogen appears at the copper electrode, and an electric current will flow through the conductor and the cell. A similar action occurs in all other cells, but the radical liberated depends on the electrolyte and the electrodes used. In *dry* cells, the electrolyte, instead of being a liquid, is carried by some absorbent material or combined with some gelatinous substance, so that, no matter in what position the cell may be put, the electrolyte will not be spilled.

Cells are *connected in parallel* when all the anodes of a battery are connected together and all the cathodes are connected together; the result is the same as if the battery were a single cell having elements the same in area as the area of the combined anodes and the combined cathodes. As the resistance of a cell varies inversely as the area of the electrodes, the resistance of the battery will be that of one cell divided by the number of cells, but the E.M.F. will not be increased.

Cells are *connected in series* when the anode of one cell is connected to the cathode of another; the internal resistance will increase, and is equal to the resistance of one cell multiplied by the number of cells. The E.M.F. of the battery will be that of one cell multiplied by the number of cells. See also Storage Batteries.

BATTERY READING. The condition of storage battery cells during charging or discharging, may be determined either by the specific gravity method, using a hydrometer, or by the voltage method in which the voltage of the cells is determined. The specific gravity method is superior to the voltage method, as the voltages denoting various conditions of the cell vary with the current as well as with the temperature, age, and condition of the plates.

BATTERY TESTS. To test primary batteries, the factors to be determined for each cell are the current and internal resistance, the E.M.F. of the cell when the external circuit is open, the polarization, and the efficiency. The current output to be desired is that at which the cell gives the greatest chemical efficiency; for open-circuit work, it may be taken as the current that the cell will maintain without a great and sudden increase in value for the longest time. The internal resistance varies with the current the cell is generating, and is determined by measuring simultaneously the difference of potential between the cell terminals and the current output, and then opening the external circuit and measuring the E.M.F. of the cell in open circuit. The lower the internal resistance, the larger is the current available for the



Batteries Connected in Series and in Parallel

external circuit. The higher the E.M.F. for a given battery consumption, the more efficient is the cell. The amount of polarization depends upon the use to which the battery will be put. It varies with the current and should be determined for the normal current that the battery is intended to generate. The chemical efficiency of a cell is the ratio of useful zinc consumption to the total zinc consumption. The useful zinc consumption is the weight of zinc that the same current will deposit during the time the cell is in operation. The ampere-hour efficiency is the ratio of the ampere-hours actually obtained to the number of ampere-hours that theoretically should have been obtained. The electrical efficiency is the ratio of the energy expended in the external circuit to the total electrical energy developed. The watt-hour efficiency is the ratio of the watt-hours expended in the external circuit to the total number of watt-hours produced.

BATTERY VOLTAGE. The cells of a battery may be connected in *series* (Fig. 1), the negative electrode (*cathode*) of one cell being connected to the

positive electrode (*anode*) of the next cell. In this case, the current given out by the battery is the same as that of one individual cell, and the voltage of the battery is the sum of the voltages of all the individual cells. The cells may also be connected in *parallel* (Fig 2), the electrodes of the same polarity on all cells being connected together. In this case, the current given out by the battery is equal to the sum of the currents given out by each individual cell, and the battery voltage is the same as that of one individual cell.

BAUMÉ HYDROMETER. The Baumé hydrometer is an instrument used for determining the specific gravity of liquids. It consists of a glass tube with a bulb at one end, containing air, and having a weight at the bottom, so that it will float in an upright position in the liquid, the density of which is to be measured. The depth to which the instrument sinks in the liquid is read off on a graduated scale which indicates the specific gravity.

BAUMGARTEL METAL. Baumgartel metal is an alloy in the Britannia-metal class, composed chiefly of tin and antimony, the composition, according to one analysis, being 81.9 per cent of tin; 16.3 per cent of antimony; and 1.8 per cent of copper.

BAUXITE. Bauxite is a soft clay-like substance, and, chemically, is the purest naturally occurring amorphous oxide of aluminum known. It contains large percentages of alumina (from 33 to 77 per cent), the chief value of which is that it is the main source of metallic aluminum. The material is first purified by chemical processes, after which the aluminum hydroxide is reduced in the electric furnace. Besides its use in the aluminum industry, it is used for the manufacture of artificial abrasives, firebrick and crucibles because of the refractory qualities of alumina. This mineral was originally found at Baux, France, from which it derives its name. The best bauxite mines in the world are those in the southern part of the United States.

BAYER PROCESS. The Bayer Process is a method of producing pure alumina from bauxite. In this process, aluminate of soda ($Na_2Al_2O_4$) is formed by dissolving the alumina in the bauxite directly in a caustic soda solution. The bauxite is first ground to about $\frac{1}{4}$-inch size pieces, then calcined or roasted to drive off the water, and after the calcined material has cooled, it is finely ground and then introduced into a 40 per cent caustic-soda solution contained in a large vessel. Steam is let into a jacket around the vessel for heating the solution, and the operation is continued for about three or four hours. About 96 per cent of the alumina content of the bauxite can be extracted in this way. The solution is filtered and afterwards passed into another cylindrical vessel through which passes a shaft with paddles for stirring the liquid. In this vessel, the solution is heated for about 36 hours, at which time about 70 per cent of the alumina in solution

will precipitate as hydroxide ($Al(OH)_3$). A small amount of hydroxide is usually added to the solution at the beginning of the process of precipitation, in order to start the reaction. The solution carrying the precipitated hydroxide is filtered under pressure. The filter cakes are dried in the air, calcined to drive off the remaining moisture and convert the hydroxide into oxide, and, in that way, practically pure alumina is produced.

BEAM. A body supported at one or more points and subjected to a load, applied at a point that is not directly supported, is known as a *beam.* The general principles of the theory of the stresses in beams and the methods of determining them are dealt with in text-books on machine design.

BEAM COMPASSES. Beam compasses, which are intended for drawing large circles or arcs, consist of a beam or strip of hard wood, carrying two heads with provision for holding a needle point and pencil-holder or pen. The head carrying the needle point is usually clamped at one end of the beam or bar, while the one carrying the pencil-holder or pen is adjusted at any point along the beam that may be required for the radius of the arc or circle to be drawn.

BEARING METALS. See Ajax Metal; Babbitt Metal; Bearings; Camelia Metal; Coleco Metal; Genelite; Hoyle's Metal; Journal Bronze; Karmarsch Metal; Lead in Bearings; Lumen Bronze; Magnolia Metal; Mercury Bearing Metal; Queen's Metal; White Metal.

BEARINGS. Bearings may be divided into two general classes: Journal bearings and thrust bearings. In the journal bearing the load acts at right angles to the axis; such bearings are also termed *radial* bearings. In the thrust bearing, the load acts parallel to the axis. Bearings may also be divided into two classes according to the manner in which the bearing surfaces are in contact with each other. Ordinary bearings have a sliding contact, whereas ball and roller bearings have a rolling contact.

When a plain bearing is running under ordinary working conditions, it will warm up until the heat radiated equals the heat generated, and the temperature so attained will remain constant as long as the conditions of lubrication, load, and speed do not change. This rise in temperature above that of the surrounding air varies from less than 10 to nearly 100 degrees F., and is commonly about 30 degrees F. The force of friction or the velocity of rubbing, or both, must be kept down to that point where the temperature shall not attain dangerous values.

Bearing Metals. — If the shaft is made of a hard and homogeneous material, like the better grades of medium steel, and the bearing is made of some soft material, like babbitt, the bearing will not roughen the journal, and so the journal cannot cut the bearing. This is the first reason why babbitt

bearings are so successful. A second reason for the success of babbitt bearings lies in the fact that they cannot be heated sufficiently to make the bearing grip the journal. They will rather soften and flow under the pressure without actually melting away, just as iron and steel soften at a welding heat. The harder bearing metals, such as brass and bronze, do not have these advantages, and have been almost entirely replaced by babbitt in bearings for heavy duty, especially when thorough lubrication is difficult. Babbitt is a successful bearing metal for still a third reason. The unit pressure on any bearing is not the same at all points. The shaft is invariably made somewhat smaller in diameter than the box. If there is a high spot on the surface of the box, that spot will have a very large proportion of the total pressure acting on it, and, as a result, the film of lubricant will be broken down at that point, and local heating and consequent damage result. In the case of babbitt bearings, before the damage can become serious the metal is caused to flow away from that point under the combined influence of the heat and pressure, the oil film is again established, and normal conditions restored.

Metal for Bronze-backed Bearings. — The S.A.E. Standard babbitt metal (specification No. 10) is very fluid and may be used for bronze-backed bearings, and especially for thin linings such as are used in aircraft engines. This metal in ingots has the following composition, the figures representing percentages; Tin, 90.75; copper, 4.25 to 4.75; antimony, 4.25 to 4.75; lead, maximum, 0.35; iron, maximum, 0.08; arsenic, maximum, 0.10; bismuth, maximum, 0.08. There should be no zinc or aluminum. When finished bronze-backed bearings are purchased, a maximum of 0.6 per cent lead is permissible in scraped samples, provided a lead-tin solder has been used in bonding the bronze and the babbitt.

The S.A.E. bronze backing for lined bearings (specification No. 66) contains copper, 83.00 to 86.00 per cent; tin, 4.50 to 6.00 per cent; lead, 8.00 to 10.00 per cent; zinc, maximum, 2.00 per cent; impurities, maximum, 0.25 per cent. This composition is recommended as an inexpensive but suitable alloy for bronze backed bearings. Good castings should have an ultimate strength of 25,000 pounds per square inch. See also Babbitt Metal for Heavy Pressures, for Light Pressures, and for Medium Pressures; see Bronze; also Phosphor-bronze.

BEARINGS, ALLOWABLE PRESSURES. The thicker and less free-flowing an oil, the greater the unit pressure it will withstand in a bearing without squeezing out. A watch oil or a light spindle oil can only be subjected to a very small unit pressure, which may not exceed 50 pounds per square inch. A cylinder oil of good body may withstand a pressure of 2000 pounds per square inch in the same bearing. A third property influencing

the allowable pressure is adhesiveness between the oil and the rubbing surfaces. The amount of pressure that commercial oils will endure at low speeds without breaking down varies from 500 to 1000 pounds per square inch, where the load is steady. It is not safe, however, to load a bearing to this extent, since it is only under favorable circumstances that the film will withstand this pressure without rupturing.

Ordinarily the allowable unit bearing pressures, in pounds per square inch, for slow or medium speeds, are as follows: Heavy lineshaft bearings with brass or babbitt lining, 100 to 150; main bearings of high-speed stationary engines, 60 to 120 for "dead load" and 150 to 250 for steam load (the "dead load" relates to the weight of the shaft, flywheels, etc.); crankpins of high-speed stationary engines, 400 to 600 for center cranks and 900 to 1500 for overhung cranks; main bearings of slow-speed stationary engines, 80 to 140 for dead load and 200 to 400 for steam load; crankpins of slow-speed stationary engines, 800 to 1300; wrist-pins of slow-speed stationary engines, 1000 to 1500; railway car axles, 300 to 325; locomotive driving wheel journals, 190 to 220; main bearings of gas engines, 500 to 700; wrist-pins of gas engines, 1500 to 2000; main bearings of marine engines, 275 to 400 for naval practice, 400 to 500 for merchant marine practice. Under exceptional circumstances, many of these values may be increased.

Bearing Pressure Formula.— The approximate unit pressure which a bearing will endure without seizing is as follows:

$$p = \frac{PK}{DN + K}$$

in which p = allowable pressure in pounds per square inch of projected area; D = diameter of bearing in inches; N = number of revolutions of journal per minute; P = maximum safe unit pressure under given circumstances at slow speed. Ordinarily the value of P is 200 for collar thrust bearings; 400 for shaft bearings; 800 for car journals; 1200 for crankpins; and 1600 for wrist-pins. Under exceptional circumstances, these values may be increased by as much as 50 per cent, but only when the workmanship is the best and the care of the bearing the most skillful; in addition, a bearing should be readily accessible and the oil of the best quality and unusually viscous. Only in the case of very large machinery, which will have the most expert supervision, can these higher values be safely adopted; K = quantity depending on method of oiling, etc. Its value may be assumed for ordinary work, drop-feed lubrication, as 700; first-class care, drop-feed lubrication, 1000; for force-feed lubrication or ring oiling, from 1200 to 1500; extreme limit for perfect lubrication and air-cooled bearings, 2000. The value of 2000 is seldom used except in locomotive work where the rapid circulation

of the air cools the journals. Higher values than 2000 may be used only in the case of water-cooled bearings.

In case the bearing is some form of sliding shoe, the quantity 240 V should be substituted for the quantity DN in the equation, V being the velocity of rubbing in feet per second.

BEARINGS, HOT-PRESSED. See Hot-pressed Soft-base Bearings.

BEARINGS, KNIFE-EDGE. See Knife-edge Bearings.

BEARINGS, OILLESS. See Oilless Bearings.

BEAVER-TAIL STOP. The " beaver-tail " stop mechanism is used in conjunction with spur gearing to prevent or minimize inertia shock or impact at some point in a repeated cycle where a clutch is thrown or tools are brought into contact with each other or with the work. The name " beaver-tail " is applied to this mechanism because of the shape of the cam which forms an important part of it. The driving pinion revolves continuously, and drives its mating gear through ordinary gear teeth except when the " beaver-tail " mechanism comes into action, at which time the motion of the gear is controlled by the two rollers and the " beaver-tail " cam. If driven gear is to be stopped once during each revolution, one cam is attached to it. If two stops per revolution are required, two cams are used. The teeth of the driven gear are cut away at each stopping position, and the large developed tooth or cam takes their place.

Rollers on the driving pinion are diametrically opposite each other, and their centers are on the pitch circle of the pinion. When the beginning of the blank space on the gear reaches the pinion and during a partial revolution of the pinion, one roller moves along the " beaver-tail " cam and brings the gear to rest with a harmonic motion. The center of the roller at the point of engagement coincides with the point of tangency of the two pitch circles, so that engagement takes place without shock. The driven gear is locked during the brief dwell which occurs while the rollers are revolving about a concentric part of the cam. After the dwell, the other roller engages the cam and accelerates the gear until it has the same speed as the pinion, when the gear teeth mesh and the ordinary gear drive is resumed. Both stopping and starting are accomplished with harmonic deceleration and acceleration, so that there is no shock to the mechanism (except from possible backlash) due to the reversal of strains.

BELL AND SPIGOT JOINT. The usual term for the joint in cast-iron pipe. Each piece is made with an enlarged diameter or bell at one end into which the plain or spigot end of another piece is inserted when laying. The joint is then made tight by cement, oakum, lead, rubber, or other suitable substance, which is driven in or calked into the bell and around the spigot.

When a similar joint is made in wrought pipe by means of a cast bell (or hub), it is at times called "hub and spigot joint" (poor usage). *Matheson joint* is the name applied to a similar joint in wrought pipe which has the bell formed from the pipe. Applied to fittings or valves, the term means that one end of the run is a "bell," and the other end is a "spigot," similar to those used on regular cast-iron pipe.

BELL CENTER PUNCH. A prick or center punch which is mounted inside of a cone-shaped bell-mouthed casing. By placing the bell-mouthed casing over the end of a bar, the prick punch is automatically located at the center of a bar with fair accuracy.

BELLCRANK. A bent lever having two arms at an angle to each other and pivoted at the point where the two arms join. Frequently, the two arms are at a right angle to each other.

BELL METAL. Bell metal is a bronze containing either 80 per cent of copper and 20 per cent of tin, or 78 per cent of copper and 22 per cent of tin. As the name indicates, it is used for bells. Many attempts have been made to substitute cheaper metals for the copper and especially for the large percentage of tin, but these have proved unsuccessful, because good tone values have not been obtained from alloys not composed of the metals mentioned and in the proportions given.

BELT-BENCH. A belt-bench is a device for maintaining belts at a required tension. An improved type of belt-bench consists of a 12-inch channel, 32 feet long, supported on eight cast-iron stands. One end of this bench-like structure has a drum-shaped casting fixed permanently to it. This drum forms a receptacle for a roll of belting and also acts as the equivalent of a pulley around which to lay a belt. A carriage that supports a revolving drum may be adjusted along the channel rail which is graduated for measuring the lengths of belts. The tension scales of the belt-bench consist of two pairs of clamps connected by screws that act through a pair of spring balances. One pair of clamps is stationary and the spring balances are attached to them; the other pair of clamps is attached to screws which, in turn, are connected with the spring balances and are rotated by a cross-shaft which is actuated by a hand crank. This crank is used for varying the tension, as indicated by the spring balances.

BELT CEMENTS. Two kinds of cement are used for joining the ends or plies of leather belting to produce what is generally termed an endless belt. One kind is referred to as "regular" belting cement and the other kind as "waterproof" belting cement. Both kinds can be obtained from the leather belting manufacturer, and either has ample strength and durability. When a belt is to be used in a dry place, where it is not subjected to

moisture, the regular belting cement is employed, while the waterproof cement is used in damp places and where the belt comes in contact with water.

Preparation of Belt Cement.— The regular cement usually comes in cakes or lumps, which are dissolved in water in a double-jacketed glue pot. Any pot with a double jacket — that is, with an inner and an outer vessel, so that the heat reaches the cement through the medium of hot water, and not directly from the flame, will serve the purpose, though it is better to use the Safety or Underwriter's glue pot, for in it the glue may be maintained under heat directly at the job, and without risk of causing fire.

The cement should be made hot, but it should not be permitted to boil. It should be reduced with hot water to a proper consistency to spread easily, and must be applied "piping" hot, to get the best results. It is desirable, too, that it should be applied fresh, and it is better not to attempt to use over the remains of a previous melting, if it is old and hard. The pot and the brushes must be kept clean, as the base of this cement, animal glue, is subject to putrefaction.

Waterproof Belting Cement.— The waterproof cement is essentially a liquid celluloid and its application places a layer of celluloid between the two surfaces of the lap, in which the leather fibres become embedded. It is unaffected by water, in any period of time, because both its base and its solvent are materials that are not soluble in water. It should be used on all belts that are exposed to damp conditions, or on which water may leak.

The solvent is very volatile, and highly inflammable, and it must be kept away from any open light. This cement is in a liquid form. Usually it is ready to spread, though after some spreading the remainder will grow thicker and should be reduced by the addition of solvent, which can be obtained from the same source as the cement. This cement is more like a varnish, and it is used cold.

Application of Waterproof Cement.— The surface to be cemented must be thoroughly coated with the cement, well brushed into the fibres of the leather, and then permitted to dry, which, because of the volatility of the solvent, takes place rapidly. When dry, another coat is applied. This coat is spread lightly and is also permitted to dry. When the second coat is perfectly dry, the belt is ready for the third and last coat. Care must be taken to apply the cement evenly and not leave any bare spots.

On belts wider than 12 inches, it is best not to attempt to cover more than a 5-inch cross-section of the belt at one time, since the solvent evaporates very fast, and it is easier to handle a small surface. When applying the last coat, the work must be done quickly. The joint should not be hammered, but rubbed gently or placed between boards, and pressure applied with the

bench screws. The joint should "set" for a couple of hours or longer before using the belt.

BELT CONVEYORS. Belt conveyors are used for carrying and transporting coal, sand, gravel, etc., for comparatively short distances. These conveyors combine a high carrying capacity with low power consumption. The belt on which the material is carried is sometimes flat, the material being fed to it at the center in a narrow stream, but, in most cases, the belt is made to assume the shape of a trough by means of guiding idler pulleys set at an angle with the horizontal and placed at intervals along the length of the belt. Rubber and cotton belts may be used for belt conveyors. The speed at which belt conveyors are run varies from 200 to 800 feet per minute.

BELT CREEP. If the driving and the driven shafts are not parallel and the pulleys are cylindrical, the belt will creep or move toward the "low side" of the pulley or toward the side where the shafts are closer. This creeping movement is due to the fact that any given point on the edge of the belt adjacent to the low side comes into contact with the pulley before a corresponding point on the opposite side. The result is that the belt is gradually shifted over toward the low side of the pulley.

BELT DRESSINGS. In many belt dressings a certain amount of resin is used and in almost all dressings some form of graphite. While both of these compositions possess certain adhesive qualities, in time they are sure to injure the fibre of the leather. If leather belting is properly curried, it seldom becomes hard or dry, unless it is working under adverse conditions. Under such conditions it is advisable to use as a belt-dressing tallow mixed with a certain amount of castor oil. The tallow softens the fibres of the leather and the castor oil restores, to a large extent, the adhesive qualities in the belt. Where trouble is experienced through slippage of the belt, a few drops of castor oil on the pulley where the slipping occurs will be found to give good results. The slippage of belts is generally due to the fact that frictional heat causes the grain or pulley side of the belting to become dry. Castor oil tends to soften the grain. A treatment that has proved satisfactory in maintaining a belt's gripping power consists in saturating the belt with animal grease or fish oil once a month, removing any surplus carefully. Before the grease or oil is applied the belt should be thoroughly cleaned.

BELT-DRIVES OF SHORT-CENTER TYPE. A short-center belt-drive is an arrangement whereby a resilient tension roller pivoted either concentric or eccentric to the axis of the smaller pulley (driving or driven) swings around this pulley, rolling and pressing on the slack side of the belt, thus increasing or decreasing the arc of contact, depending on the increasing or

decreasing of the load, and thereby maintaining the same stress in the slack side, regardless of the elongation of the belt. The tension may depend upon the weight of the roller and its frame or provision may be made for adjustment. The terms "belt tension-roller," "swinging-frame belt tightener," and "gravity idler" are also applied to this device. See also Lenix Belt Drive.

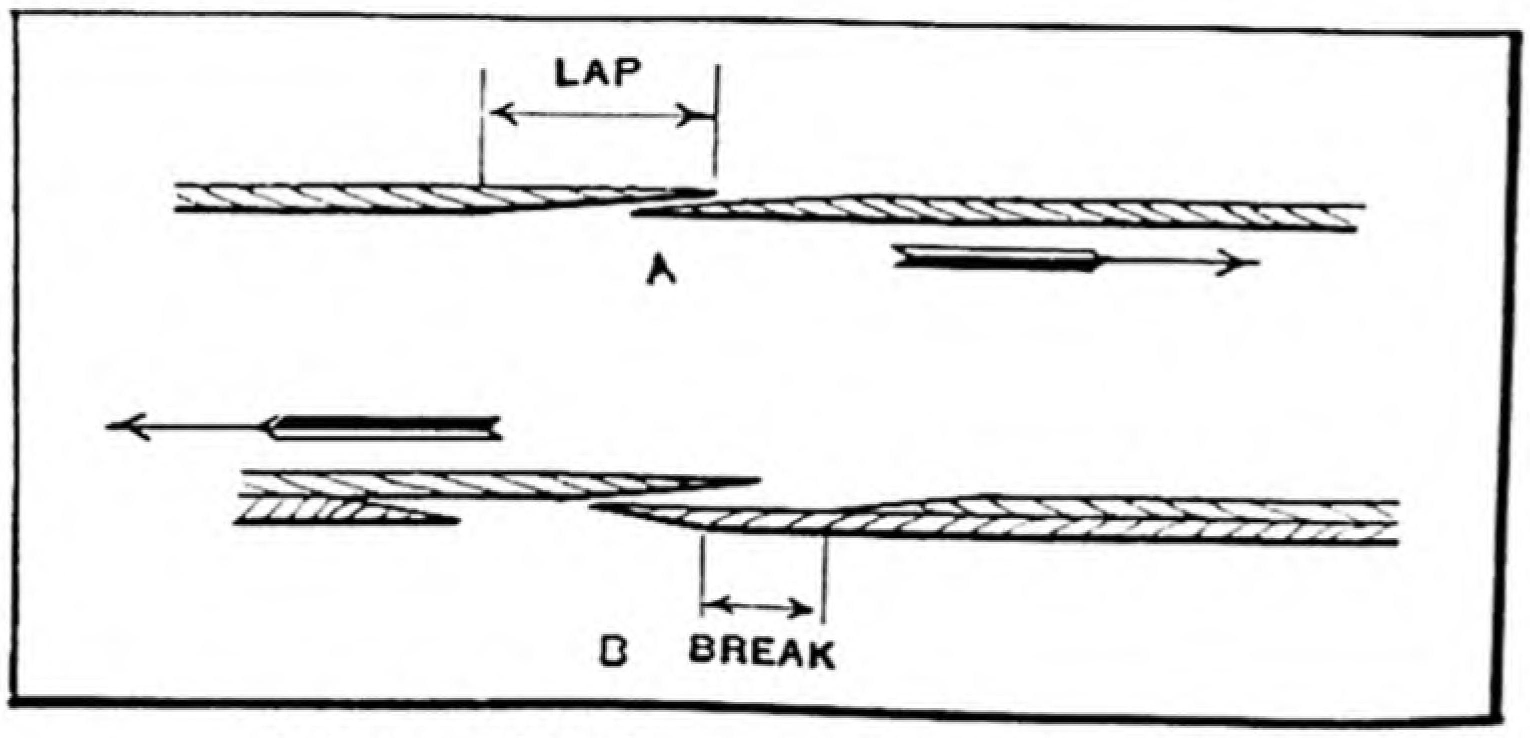
BELT-DRIVES, QUARTER-TURN. See Quarter-turn Belt-Drives.

BELT GRIP AND TENSION. "Belt grip" and "belt tension" are two terms that are frequently confused. A belt can be made to grip a pulley effectually by increasing its tension, but this throws an undue strain on the driving shafts and often causes hot journals. On the other hand, belts that are properly treated with suitable dressings can be made to grip the pulleys effectually even though running slack. The importance of grip as distinguished from tension cannot be too fully appreciated. Some are of the opinion that when a belt fails to transmit the required power it should have its tension increased by tightening. The effective pulling power of a belt is the difference in the tension on the slack and tight side. It is obvious that the greater the grip of the belt on the pulley, which increases proportionally with the arc of contact, the greater power it will transmit. It follows, therefore, that a belt running slack, provided it grips the pulley effectively, will give a better grip over a greater arc of contact than a tight belt, and that at the same time the loss of power due to friction will be reduced. Some forms of belting possess less elasticity or resiliency than others and thus transmit power more by sheer weight and tension than by gripping power. The limit of the decrease of the tension value on the slack side of a belt is at that point at which the belt slips on the pulley, the maximum pulling power being attained at the moment preceding the slip. From this it follows that the value of a pliable belt lies in the fact that the tension on its slack side may be decreased to a much greater extent than is the case with a hard belt before slipping becomes evident.

BELT INSTALLATION. Whenever practicable, belts should be installed so that the slack side is above and the driving side below the pulleys. When this condition is reversed and the slack side is below, the arc of contact and consequently the driving power is materially lessened. In the case of leather belts, these should be placed on the pulleys with the hair or grain side next to the pulley rims. When installing belts, it is also important to provide the right amount of tension, assuming that a tension roller is not used. See Belt Grip and Tension. Certain kinds of belting are affected by the weather conditions, and lengthen or shorten according to the amount of moisture in the atmosphere. Belts and pulleys should be kept clean and free from accumulations of dust and grease, and particularly lubricating oils,

some of which permanently injure the leather. They should be well protected against water, and even moisture, unless especially waterproofed.

BELT JOINTS. Leather belts usually are made endless by overlapping the wedge-shaped ends and cementing them together with belt cement. The method of overlapping depends upon the size of the belt, whether single, double, triple, or quadruple. The single-belt lap is shown at *A* in the accompanying illustration. Both ends must be square with the sides of the belt and the beveled sections are given a fine feather edge.



Joints of Single- and Double-ply Belts

The length of lap for single belts is: 6 inches for belt widths up to 5 inches; 8 inches for widths from 6 to 8 inches; 12 inches for widths from 9 to 11 inches; and 14 inches for widths from 12 to 14 inches. The skived-down ends of the new lap must follow the same direction as the other laps of the belt, which should run with laps pointing as shown at *A*. A single belt is always put on with its smooth or hair side next to the pulley, the rough or flesh side being outside.

A commonly used lap for double leather belts is shown at *B*. The "break" varies according to the width of belt, and may be made as follows: 6 inches for belt widths up to 6 inches; 8 to 12 inches for widths from 6 to 18 inches; 18 inches for widths from 20 to 24 inches; and 24 inches for widths over 24 inches. Double belts must run with the laps pointing as shown at *B*; it is immaterial which side is put next to the pulley.

BELT MATERIALS. Belts for power transmission may be made either from leather, rubber, canvas, or thin sheet steel. Leather belts are, by far, the most commonly used. Rubber belts are used when the belt is exposed to the weather conditions or to the action of steam, because they do not stretch as easily as leather belts, under these conditions. Canvas belting is used when the materials in contact with the belt and the surrounding atmosphere would affect a leather or rubber belt. Steel belts made from thin flat strips have been introduced within comparatively recent years.

Belts Made of Leather.— The best grades of leather belting are made from a comparatively small section of a hide. That part of the hide extending along the spine and for some distance down the sides is firm and close in texture and the strongest for a belt. If the leather is taken too far down the side, it will be flexible and lack strength and closeness of texture. If the

strips are cut too long, the ends will be taken from the neck of the animal, which is also inferior stock. A " short lap " belt is one made entirely from that part of the hide which comes from the back of the animal and the strips are not long enough to include any portion of the neck stock. The use of the poorer grades with the best grades of leather belting is particularly bad. The inferior grades soon stretch, throwing almost the entire stress of belt pull on the superior grade. This uneven tension quickly deteriorates the belt. Probably a belt made up in this manner is inferior to that made of the poorer grades throughout. Making the belt of inferior grades throughout has the merit of equalizing the stretch, keeping both parts in even tension. Oak-tanned leather is often considered the best for belting, although many high-grade belts are no longer tanned by the use of oak bark. Assuming that a good grade of leather is used, uniformity in the material is of first importance; that is, the different sections of which the belt is made should all be of the same grade. The belts should also be thoroughly stretched so that they do not have to be " taken up " every few days.

Piping Test for Belt Leather. — Leather in the lower half of the hide, with its longer and looser fibres, is softer and spongier than the upper part, and that the grain surface of the leather is not so firmly attached to the inner fibre; hence, in bending this leather, it will develop usually into wrinkles or " pipes " in the grain. It is possible to produce " pipes " in almost any piece of leather by bending it often enough and close enough, and applying sufficient force. A single leather belt should not show piping when bent over a form 2 inches in diameter; or a double belt when bent over a form 4 inches in diameter.

Practically all belly leather stock will show piping under this test, even when it has been rolled hard to prevent it from showing, and hence it is not desirable for belting purposes. Occasionally, pieces from the upper part of the hide will show piping under this test, but regardless of the part of the hide from which the piece is taken, the presence of piping indicates a loose grain and a flabby fibre in the leather, which is not conducive to durability in the belt, and in most cases indicates the presence of belly stock. There is another test to be applied by bending the leather over the same form, with the grain side on the outside, to detect cracking in the grain, and if this test develops a series of minute cracks running across the width of the belt, it may be deduced that the material either is not properly tanned or is not properly curried, and that it is not suitable for good belts.

Belts Made of Fabrics. — Among fabric belts (aside from rubber belts), the solid woven, impregnated cotton belt seems to take first place as a substitute for leather belts. Balata and stitched canvas belts, which are made up of plies similar to rubber belts, apparently have not been able to get a firm hold in the field of power transmission. A comparison of these types

of belting shows that balata and stitched canvas belts possess a definite maximum of power transmission beyond which it is impossible to go, and that this maximum capacity is far below the capacity of leather belts. The solid-woven cotton belt seems to be the only fabric belt which nearly approaches the capacity of a leather belt. The stretch of this cotton belting in service is about the same as leather, and, like all cotton belting, it is affected by moisture and high temperature, although the effect is the reverse of the effect on leather. In damp places leather stretches and cotton shrinks; the changes in length, however, due to changes in atmospheric conditions, are much less for cotton than for leather, due to the treatment which cotton belts undergo. Although solid-woven cotton belts do not have the durability of leather belts, their flexibility is great and they can be used on the smallest pulley without much loss through bending, and without subjecting the belt to greater strain. They are unaffected by grease, grit, mineral oils, or heat.

Belts Made of Steel. — Thin, flat steel belts have been used to some extent, and tests are said to have demonstrated the following advantages: Steel belts can transmit much more power for the same width; they are not affected to any appreciable extent by temperature changes or changes in the humidity of the air, which adapts them for use in damp places, and there is little stretching or slipping. Steel belts must be so installed as to insure that the power is evenly distributed over the full width of the steel band, as otherwise one edge might be stressed beyond its breaking strength, with the result that the entire belt would fail. The pulleys for steel belts must be cylindrical and not crowned. Steel belts run fairly well on smooth cast-iron pulleys, but after a time there is a tendency to polish the surface of the pulley; hence it has been found desirable to cover the rim with thin cork, which is glued to a piece of canvas cemented to the pulley. There is practically no slip on pulleys treated in this way. Steel belts can be run at speeds as high as 10,000 feet per minute.

Endless steel belts are manufactured from alloy steels that are rustless and stainless, and are said not to be affected by high or low temperatures, or by oil, moisture, acids or changing atmospheric conditions. They are made to order for specified applications in sizes ranging from 6 to 100 feet in length, and from 1 to 6 inches in width, for operation over pulleys 6 inches in diameter and larger. They are also made in certain standard lengths and widths for general applications over pulleys 8 inches in diameter and larger. The normal capacity for the standard sizes is approximately 8 horsepower per inch of width. See also Rubber Belts.

BELT POWER-TRANSMITTING CAPACITY. Power ratings for belt drives vary considerably, according to different authorities and investiga-

tors, even for belts of the same kind and applied under similar conditions, as will be seen by a comparison of the conclusions found in text-books, articles, and the literature published by belt manufacturers. The general formula for determining the power rating follows:

$$H = \frac{SVW}{33{,}000}.$$

In this formula, H = horsepower; S = effective belt pull, in pounds per inch of width; V = belt velocity, in feet per minute; and W = belt width, in inches.

The effective pull or difference between the tensions on the tight and slack sides is the variable factor. This factor is affected by belt velocity and arc of pulley contact, by belt thickness and its relation to the pulley diameter, as well as the kind and quality of the belting. Even for the same belt quality, wide differences of opinion exist as to the amount of pull per unit of width or area that is conducive to the best results when initial cost, durability, and everything pertaining to it are allowed for. If the working load is excessive, the life of belting will be reduced accordingly and the load on the bearings increased. On the other hand, if belts are given too low a rating, this means that wider and more expensive belts will be installed than is necessary. Somewhere between these extremes is the most economical rating, which is based, not only upon the initial cost of the belt but also upon all subsequent costs connected with that particular installation.

BELT SHIFTERS. When belt-driven machine tools such as lathes, milling machines, etc., are equipped with cone pulleys, the shifting of the belt from one step of the pulley to another is somewhat dangerous when done by hand and may be quite difficult, especially when the overhead countershaft is comparatively high and the belt is under considerable tension. In order to facilitate the changing of belts on cone pulleys, mechanical shifting appliances of various kinds have been devised.

BELT SPEEDS. Low belt speeds are often the cause of inefficiency and waste of power. Whenever possible, belts for transmitting power should be run at from 4000 to 4500 feet per minute, while they are frequently run at only 1000 feet per minute. As a result, wide belts are being used when a narrower belt, running at a high speed, would prove both cheaper and better. In addition, bearing pressures would be lessened and the friction and accompanying wear and power consumption reduced; thus, the expense for belts, fuel, and oil would be decreased to a considerable extent.

BELT STRETCH. The stretch of a leather belt is considerably less at higher than at lower velocities. Numerous tests made with open belt

drives have shown that the stretch varies from 5 per cent to 18 per cent of the belt length. While the foregoing holds true for open belt drives, quite different results have been attained with short-center belt drives. Investigations of these belts after they had been in operation from six to ten months, showed a stretch of only 0.95 to 1.12 per cent, most of this stretch occurring during the first months of service. Thereafter no appreciable stretch took place, and the tension roller remained in its normal position. This shows that the excessive belt stretch on an open drive is due chiefly to its uncontrollable initial tension (the tension of the belt when at rest). This tension is uncontrollable because it is affected by humidity. On a short-center drive, the initial tension is eliminated almost entirely, and the stress in the slack strand of the belt is only a fraction of the stress in the slack strand of an open belt drive. This is a result of the high ratio of tensions 1:5 to 1:10 — according to the belt velocity — as against 1:2 on an open drive. Inasmuch as the tensions in the slack and tight strands of a belt are equal when at rest, it is reasonable to assume that the tension in the belt of a short-center drive at rest amounts to almost nothing; furthermore, the humidity has no influence on the stress of the belt, due to the tension roller. These facts account for the comparatively small stretch.

BELTS, V-TYPE. The included angle of the sides of rubber V-belts (according to the S.A.E. recommended practice) should be 32 degrees when apparatus other than the fan is driven by the same belt, and 42 degrees when the fan alone is driven, to allow for the bulging of the inside of the belt when laid around the pulleys. The included angle of the pulley groove should be 28 degrees for the 32-degree belt and 38 degrees for the 42-degree belt. The width of the pulley groove measured at the outside diameter of the pulley should be greater than the maximum belt width. V-belts having a width of $\frac{5}{8}$ inch at the top should have a minimum clearance space between the bottom of the belt and the pulley groove of $\frac{1}{8}$ inch. This clearance should be increased to $\frac{3}{16}$ inch for belts $\frac{3}{4}$ inch and 1 inch wide at the top, and increased to $\frac{5}{16}$ inch for a belt width of $1\frac{1}{4}$ inches.

BELT TENSION SCALE. See Tension Scales for Belts.

BELT WEIGHT PER SQUARE FOOT. The weight of oak-tanned leather belting varies from 12 to 18 ounces per square foot for single belts and from 22 to 33 ounces per square foot for double belts, according to the brand and thickness. The average weight of rubber belting per square foot and ply is: 0.3699 pound for 28-ounce duck; 0.3893 pound for 32-ounce duck; and 0.4923 pound for 36-ounce duck. To find the weight per lineal foot of a rubber belt, multiply the weight per square foot and ply by the number of plies and the width of the belt, in inches, and divide by 12.

BENCH LATHE. The modern bench lathe finds wide application in the manufacture of small parts requiring considerable accuracy, as well as in fine tool work, where its facility of operation and its accuracy make it an ideal tool. Bench lathes have been developed to the same high standard of efficiency as the heavier types of lathes, and the design of various attachments has broadened the field of these machines so that they are able to handle a wide range of work. In addition to their adaptation to precision turning and boring operations, bench lathes may be equipped with attachments for milling and grinding, for chasing, cutting, and milling screw threads, for turret work, filing, and a variety of other operations. Many of these attachments, such as those for milling, grinding, threading, etc., are standard equipment supplied by bench lathe manufacturers, but many special attachments are also used in connection with bench lathe practice.

BENCH LATHE MILLING ATTACHMENTS. Bench lathes are often used for milling in connection with such operations as fluting special reamers, taps, counterbores, or other cutters, and making small punches, dies, pinions, etc. Milling attachments vary in regard to the range of adjustment and methods of applying to the machine. For instance, some have a single vertical slide with or without a swivel or angular adjustment and are mounted upon the regular compound slide in order to obtain cross and lengthwise movements. Other milling attachments are mounted directly on the bed in front of the headstock, and have their own slides, as well as swivels for angular adjustment in two planes. Another variation consists in bolting the attachment to one end of the bed, instead of locating it on the bed or slide-rest. One design is held to the right-hand end of the bed, and another to the left-hand end, the headstock in the latter case being reversed. The most common practice is to use the milling attachment for holding the work and the lathe spindle for driving the cutter, but some attachments are designed to drive the cutter, which operates upon work while it is held in the lathe spindle.

BENCH LATHE TAILSTOCKS. In bench lathe practice, the tailstock is frequently used as a means of holding and feeding various classes of tools. Tailstocks for bench lathes are made in several different forms. The type intended primarily for supporting one end of centered work is designed along the general lines of the well-known engine lathe tailstock. Then there is a lever-operated tailstock for drilling, reaming, counterboring, and similar operations. Another form is operated through a rack and pinion in conjuncton with a hand-lever. The cross-slide adjustment provided in this case is useful for recessing, facing, and counterboring. The " half-open " tailstock is employed for light operations such as drilling, reaming, lapping, and the cutting of very small threads with taps or dies, while the revolving-

spindle tailstock is applied to certain drilling operations. The "sliding" or "open" tailstock is similar to the half-open design, except that it has full or complete bearings. The spindle has a knob at one end and is moved by hand the same as the spindle of a traverse grinder.

BENCH LATHE TOOL-SLIDES. For certain operations on bench lathes, it is preferable to operate the tool-slide by a hand-lever instead of using an ordinary feed-screw, on account of the more rapid movement obtained. The connection between a hand-lever and slide may be direct or through a pinion meshing with a rack attached to the slide. If the manipulation of the ordinary feed-screw is too slow and a direct-acting lever does not give quite the feeding power needed, then a hand-lever which acts through the medium of a rack and pinion is the best combination.

BENCH LATHE TRAVERSE-SPINDLE GRINDER. The traverse-spindle grinding attachment is so named because the spindle is free to slide in its bearings, and is traversed either by means of a knob at the rear end, or by placing the belt pulley between the thumb and forefinger. Such attachments are generally used for grinding or lapping holes, but they are also very satisfactory for external grinding, particularly on short end surfaces and whenever a light sensitive control is essential. Many light drilling, reaming, and milling operations are also done with the traverse-spindle attachment which is also called a "push spindle" and a "slide-spindle" attachment.

BENCHES. The height of work-benches usually varies from 32 to 36 inches from the floor to the top of the bench, the height depending somewhat upon the nature of the work, lighter work being done on higher benches. For general purposes, the height should be about 34 inches; the width should be about 30 inches, and the top is ordinarily composed of heavy planks, 2 or 3 inches thick, in the front, and lighter 1-inch boards in the back. The thickness of the front planks is varied in accordance with the weight of the work for which the bench is intended. Maple and ash are considered the best woods for bench planking. The preferable positions for benches, especially if used for fine accurate work, is the north side of the building, because the light on that side is more even throughout the day.

BENDING BRAKE. See Brakes for Bending.

BENDING DIES. Dies of this class are designed for bending sheet metal or wire parts into various shapes which are usually irregular and are produced either by pushing the stock into cavities or depressions of corresponding shape in the die or by the action of auxiliary attachments such as slides, etc., which are operated as the punch descends. A simple form of bending die would be one having an upper part or punch shaped to correspond with a depression in the die-face; such a bending die is sometimes employed for

bending flat, sheet-metal plates into an irregular shape. When the material to be bent is elastic or springy, the die must be made to allow for this, or so that the part is bent slightly beyond the required shape or angle to compensate for the backward spring when the pressure is released. Determining this allowance is a matter of experiment.

BENDING PIPES AND TUBES. See Pipe Bending.

BENEDICT NICKEL. An alloy containing, according to the U. S. Navy specifications, from 84 to 86 per cent of copper with the remainder nickel. It is used for condenser, distiller, feed water heater, and evaporator tubes.

BENEFICIATION OF IRON ORE. The term "beneficiation" is applied to those processes used for the improvement of ores which result in producing an ore which contains a greater percentage of the metal to be extracted than the original mined product. It is also applied to those methods which change the physical and sometimes the chemical properties of the ore so that it will meet the requirements for a commercial product. In the past, the term "beneficiation" has been applied to ores of precious metals only, but at the present time it is also applied to the ores of other metals, such as iron. When the process produces a richer ore, more than one ton of raw material is required to produce one ton of the beneficiated ore; for example, an ore containing 40 per cent of iron may be concentrated so that it yields an ore containing 60 per cent of iron, but it is evident that at least $1\frac{1}{2}$ ton of the 40-per-cent ore must be used to produce one ton of the concentrated 60-per-cent ore. There are various methods by means of which beneficiation of iron ore may be carried out.

BERNARDOS ELECTRIC WELDING PROCESS. An arc-welding method in which an electric arc is drawn between the metal to be welded. The metal forms one electrode of a circuit and a carbon electrode is manipulated by the workman. The metal is fused by the high temperature of the electric arc, and filling material is provided by a metal filling rod, the end of which is held and melted in the arc.

BERRITE. Berrite is a gum used for impregnating paper and cloth in order to make them suitable for electric insulating materials. This gum is not affected by high temperatures, and materials impregnated with it are tough, but will easily crack. It is estimated that the puncturing voltage for this insulating material is about 5000 volts per millimeter (0.039 inch).

BERYLLIUM. A rare metallic element also known as *glucinum*, belonging to the same group of metals as magnesium, the chemical symbol of which is Be. (When the name "glucinum" is used, the chemical symbol Gl is

employed.) The metal is malleable. Its specific gravity is 1.64, its atomic weight, 9.1, and its melting point about 1800 degrees C. (about 3275 degrees F.).

BESSEMERIZING OF MATTE. A method used for refining copper which is similar to the Bessemer process used for making steel from pig iron; see *Manhès process*.

BESSEMER ORE. An iron ore containing such a small percentage of phosphorus that it is suitable for making pig iron which can be converted into steel by the acid Bessemer process. Such ore must not contain more than 0.07 per cent of phosphorus.

BESSEMER PIG IRON. A name applied to iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid Bessemer process (restricted to pig iron containing not more than 0.10 per cent of phosphorus).

BESSEMER PROCESS. The Bessemer process of converting iron into steel is also known both as the *pneumatic* and the *fuelless;* by this process, the carbon, silicon, and manganese of molten iron, and often the phosphorus and sulphur as well, are oxidized and removed by air forced through the metal. Hence, in the Bessemer process, the product of the blast furnace may be converted into steel, thus reducing the cost of raw material for all but the highest grade of steel. The process was invented and patented in England by Sir Henry Bessemer, in 1855.

In the Bessemer process, the impurities are removed by passing air through the molten metal in many fine streams and so rapidly that the heat produced by the oxidation of these impurities is sufficient to raise the temperature of the iron from just above the melting point of cast iron to considerably above the melting point of steel.

After the converter is charged, for which purpose it is placed in a nearly horizontal position, the blast is turned on, and then the converter is placed vertically. The blast pressure is sufficient to prevent the molten iron from passing through the tuyeres into the wind box. At first, only the nitrogen of the blast passes through the metal, as the oxygen is consumed in the oxidation of silicon and manganese; as a result, no flame appears at the mouth of the converter; but, when the silicon and manganese are nearly gone, the carbon is converted into carbon monoxide by the blast, which burns at the mouth of the vessel, producing an intensely bright flame that rapidly increases in size. When all the carbon is burned, the flame drops quite suddenly, which is a sign that the process is completed. The steel is then discharged by again placing the converter in a horizontal position and shutting off the blast.

Acid Process. — The original, or acid, Bessemer process is limited to comparatively fine pig irons, because dephosphorization and desulphurization do not take place. In this process, the bottom is made by putting the hard-burned fireclay tuyeres in position and then dumping in ganister until the layer is from 26 to 30 inches thick; the usual life of this bottom is from 30 to 35 heats, although some burn out in a single heat, while others last for 50 or 60 heats.

Basic Process. — The basic process makes available, for the making of steel, iron that is too high in phosphorus for the acid Bessemer process and for economical use in the ordinary basic open-hearth process. It was at first known as the *Thomas-Gilchrist process*, from its inventors S. G. Thomas and P. C. Gilchrist. It differs from the acid process in that the slag is made very basic by the addition of considerable lime, the converter lining is basic, the process is not arrested at the drop of the flame, and the oxidation of phosphorus is the source of the heat. In the basic process, the converter used is from 50 to 60 per cent larger than the acid converter for the same iron charge. Its lining is from 12 to 24 inches thick at the bottom and from 8 to 16 inches thick at the nose; its bottom is from 20 to 26 inches thick. The average life of this converter is about 100 heats.

Because of their short life, basic converters are generally installed in sets of three, so that two converters may be working while the third is being relined. In the acid method, the blast has a pressure of from 20 to 30 pounds to the square inch and the heat is completed in from 7 to 12 minutes; in the basic process, the blast has a pressure of from 25 to 35 pounds, and the heat requires from 15 to 18 minutes. The action during the first part of the basic process is similar to that of the acid; but the latter part, known as the "afterblow," is distinctive; it is at this stage that the phosphorus is removed.

BESSEMER STEEL. Steel made in a Bessemer converter in which the carbon and impurities are removed from the charge of molten pig iron by blowing air up through the metal. A steel of fair quality is made by this process, which is cheap and rapid. Most steel is now made by the open-hearth process.

BEVEL GEAR. Bevel gearing is used for transmitting motion between two shafts located at an angle to each other (usually a right angle) and normally having center lines which intersect or lie in the same plane. By using special teeth, it is possible, as in "hypoid gears" and also "skew" bevel gearing, to have the center lines of the driving and driven gears in different planes, one shaft being offset somewhat relative to the other shaft.

When the number of teeth in two gears is the same they are called *miter gears*, the pitch cone angle of each gear being equal to 45 degrees. The

term *acute angle bevel gearing* is applied when the center angle or angle between the axes of the shafts is less than 90 degrees. *Obtuse angle bevel gearing* connects shafts having a center angle greater than 90 degrees.

If the pitch cone angle of a bevel gear equals 90 degrees, the gear is known as a *crown gear*, the pitch cone in this case being a pitch plane or disk. If the pitch cone angle exceeds 90 degrees, the gear is an *internal bevel gear*. The teeth of two bevel gears in mesh converge toward a common center. This converging tooth form must be obtained in cutting the teeth by a generating process, although an approximate shape can be obtained by the formed cutter process. See also Hypoid Gears; Skew Bevel Gears; Spiral Bevel Gears.

BEVEL GEAR FORMED CUTTER. A bevel gear cutter is made thinner than a spur gear cutter because it must pass through the narrow tooth spaces at the inner ends of the teeth. For $14\frac{1}{2}$-degree involute teeth, there are eight cutters numbered from one to eight for each pitch and suitable for cutting bevel gears from a 12-tooth pinion to a crown gear. The cutter to use, in any case, must not only be of the required diametral pitch but the right number in the series. The number of the cutter depends upon the number of teeth in the gear or pinion. When cutting miter gears, only one cutter is needed, but, if one gear is larger than the other, two cutters of the same pitch but of different numbers may be required.

The number of teeth for which to select the cutter is not the actual number of teeth in the gear, but is found as follows: Divide the actual number of teeth in the gear by the cosine of the pitch-cone angle. For instance, if the bevel gear is to have 35 teeth or 12 diametral pitch and the pitch cone angle is 60 degrees, the number of teeth for which to select the cutter equals $35 - 0.5 = 70$. Therefore, a number 2 cutter of 12 diametral pitch would be used, since this number in the series is intended for numbers of teeth from 55 to 134. Cutter number 1 is for cutting gears with number of teeth ranging from 135 to a rack; number 2 from 55 to 134, number 3 from 35 to 54; number 4 from 26 to 34; number 5 from 21 to 25; number 6 from 17 to 20; number 7 from 14 to 16; and number 8 from 12 to 13.

BEVEL GEAR GENERATING PROCESSES. In cutting spur gears by generating methods, the rack of involute gearing is represented either directly by the cutter used, or indirectly as when a circular form of cutter is generated from the rack. The relation between a rack and spur gear is similar to that of a crown gear to a bevel gear; thus the pitch surface of a rack and also of a crown gear coincides with a plane. The teeth of a crown gear are also straight sided like those of a rack, although of converging form. and the inclination of each side corresponds to the pressure angle. The cutting tools of bevel gear generators, therefore, represent the crown gear

and when a bevel gear is being cut the tooth curves are derived by imparting to the work and to the cutting tool the same relative motion that would be obtained if the gear being cut were rotating in mesh with the crown gear. In addition to this generating motion, provision must be made in a practical design of machine for giving the tool or tools a reciprocating motion for cutting, and an indexing movement to the work in order to cut equally spaced teeth around the entire gear.

The generating motion on some other machines is obtained by rolling the gear being cut, relative to the cutting tool (representing a crown gear tooth) just as though this gear were finished and rolling around a stationary crown gear. Thus all the generating motion is applied to the work; the cutting tool is simply given a reciprocating motion for planing. A common type of bevel gear generator is so designed that the generating action is applied to both the work and to the cutting tools. In this case the action is similar to that of a crown gear rotating in mesh with the gear being cut, each gear revolving about a fixed axis.

BEVEL GEAR RATIOS. When the pressure angle of bevel gearing is $14\frac{1}{2}$ degrees (the angle commonly used outside of the automotive field) the minimum numbers of teeth on the pinion, recommended for different gear ratios, are as follows: Ratios from 6 to 1 down to and including 3 to 1 should have pinions with not less than 21 teeth; for a ratio of 2 to 1, 19 teeth; for $1\frac{1}{2}$ to 1, 18 teeth; for 1 to 1, 14 teeth.

BEVEL GEARS, GLEASON SYSTEM. The system of bevel gears introduced by the Gleason Works is designed to give the quietest form of tooth consistent with strength and wearing qualities. The basis of the system is in using the lowest pressure angle that can be employed without sacrificing strength by introducing excessive under-cut. The use of a low pressure angle in preference to a higher one does not reduce the effective strength to the extent ordinarily supposed, because the stronger tooth section of the higher pressure angle is offset by the greater arc of action with the lower angle. With this system the gear addendum is decreased and the pinion addendum is increased as the ratios of the numbers of teeth in the gear and pinion become greater. The system has three pressure angles of $14\frac{1}{2}$, $17\frac{1}{2}$, and 20 degrees for all straight-tooth bevel gears having ten or more teeth in the pinion, and one angle of $14\frac{1}{2}$ degrees for spiral bevel gears, except in a few special cases. This system is applicable to any pair of generated spiral- or straight-tooth bevel gears operating at right angles, where the pinion is the driver and, in the case of straight tooth gearing, has ten teeth; spiral bevel gears having less than ten teeth are included in the system.

BEVEL GEARS OF SPIRAL TYPE. The essential feature of a spiral bevel gear is that the tooth is curved instead of straight. The curve, if

continued, would intersect the cone center of the gear. This feature distinguishes the spiral type bevel gear from the skew bevel gear in which the tooth elements are straight, and do not intersect the cone center, if extended The teeth of spiral bevel gears are not a true spiral, although the actual curve, when developed on a plane, closely approximates the spiral curve.

Spiral type bevel gears are used widely in automobile rear axle drives in preference to bevel gearing having straight teeth. There has also been an increasing demand for this type of gearing for other purposes. The spiral design operates more smoothly and quietly than bevel gears with straight teeth due to the overlapping of the teeth. One pair of teeth is engaging while the preceding pair is still in contact, and the engagement is gradual, so that the teeth, instead of striking a full-line contact at once, roll onto each other with an action which suggests the smoothness of a worm and worm-wheel; nevertheless, the action is purely a rolling action, as in the case of straight-tooth gears. Another point of advantage is the range of endwise adjustment of the pinion, which is possible without introducing noise or spoiling the bearing of the teeth. This range of adjustment is greater than that obtained with straight-tooth bevel gears.

The spiral type of gears is especially well adapted for high-ratio drives; 10-, 11-, and 12-tooth pinions are used in ratios up to 6 to 1 with satisfactory results. The use of pinions with such a small number of teeth makes it possible to use a small diameter. The load-carrying capacity of spiral type bevel gears is practically the same as for straight-tooth gears, and this type of gear has been substituted, in many cases, for straight-tooth gears, of the same number of teeth and pitch, with satisfactory results.

BICHROMATE CELL. A primary cell or battery having a zinc anode, a carbon cathode, and an electrolyte consisting of potassium or sodium bichromate, or chromic acid, dissolved in water with the addition of a little sulphuric acid. The bichromate dissolved in the electrolyte acts as a depolarizer. The cell may be used for open or closed circuits, but the elements should be removed from the electrolyte when it is not in use. The electromotive force developed is from 1.9 to 2.1 volts.

BICYCLE ORIGIN. The bicycle was invented by Baron von Drais of Manheim. This was exhibited in Paris in 1816. It was without pedals and was propelled by using the feet in contact with the ground to push the bicycle. In 1855 Michaux, a Frenchman, applied for the first time cranks and pedals to the axle of the drive wheel. In 1877 Rosseau of Marseilles used a chain and sprocket type of drive.

BILATERAL TOLERANCE. A bilateral tolerance is a tolerance given in two directions (plus and minus) from the basic dimension. For examples of both bilateral and unilateral tolerances see under Tolerances.

BILLET. A "billet," as the term is applied in rolling mill practice, is square or round in section and from 1½ inch in diameter or square to almost 6 inches in diameter or square. Rolling mills used to prepare the ingot for the forming mills are termed "blooming mills," "billet mills," etc.

BILLET MILLS. See under Rolling Mills.

BINARY ALLOY. An alloy containing two elements. When the term is used in regard to iron or steel, it refers to a material that has one alloying element in addition to iron. Since carbon is always present in steel, plain carbon steel is the typical binary iron alloy.

BINDER. The material used for holding together the sand in a dry sand core is known as a binder. Various dry compounds made from rosin, dextrine, coke dust, and pitch, as well as pastes made from flour, are used as core binders. Linseed, fish, and mineral oils, and molasses and glue dissolved in water, are also used.

BIRMINGHAM WIRE GAGE. The Birmingham or Stubs iron wire gage is used for seamless tubing, sheet spring steel, strip steel and to some extent for galvanized iron telegraph wire. (Stubs iron wire gage differs from Stubs steel wire gage.) The Treasury Department of the United States for many years used this gage in connection with importations of wire, and the adoption of succeeding tariff acts with provisions for the assessment of duty according to gage numbers gave legislative sanction to the gage, but, in 1914, its use by the Treasury Department was finally abandoned.

BISBEE CONVERTER. Also known as *Leghorn converter* and *trough converter*. See Trough Converter.

BISMUTH. Bismuth is a metallic element, which occurs as pure metal in veins in gneiss or clay-slate, and is frequently found in combination with ores of silver and cobalt. It is found in Saxony and in Bohemia, and also in Cornwall, England, but it is most abundant in Bolivia, which is the chief commercial source of the metal. Bismuth is a very brittle metal with a white-crystalline fracture and a reddish-white color. One of its important qualities is that it expands on passing from the molten to the solid state, and that it retains this property in a number of alloys; hence, it is frequently used with antimony in type metals, because it fills the mold completely upon solidification. Its most important use, in fact, is in alloys with other metals, and it forms an important ingredient in many of these.

One of the so-called britannia metals is composed of 50 per cent of antimony, 25 per cent of bismuth, and 25 per cent of tin. A good alloy for pattern letters contains 15 per cent of antimony, 15 per cent of bismuth, and 70 per cent of lead. An important use of bismuth is in alloys requiring a low

fusing point. Fifty parts of bismuth alloyed with 25 parts of lead, 12.5 parts of tin and 12.5 parts of cadmium will melt at a temperature of 149 degrees F. Bismuth added to lead hardens and toughens the latter metal. An alloy consisting of 40 per cent of bismuth and 60 per cent of lead has ten times the hardness and twenty times the tensile strength of lead. Alloys of bismuth with either lead or tin can be easily cast, and fill the molds well. Bismuth alloys have been used to some extent for fusible plugs for boilers, but it has been found that the continued action of heat changes their melting point so that they cannot be depended upon to melt at the right temperature. The U. S. Navy Department specifies pure Banca tin for fusible plugs.

The atomic weight of bismuth is 208.5 (some authorities give the value as 208.0); the chemical symbol is Bi; the specific gravity, 9.8; the weight per cubic inch, 0.354 pound; and the weight per cubic foot, 611.5 pounds. The melting point is 271 degrees C. (520 degrees F.). Its thermal conductivity is lower than that of all other metals, it being 1.8 as compared with 100 for silver; its electric conductivity is from 1.2 to 1.4 (silver = 100); its coefficient of expansion per unit length, per degree F., equals 0.00000975; its specific heat is about 0.0306; and its tensile strength about 6400 pounds per square inch. At atmospheric pressure it vaporizes at temperatures above 1100 degrees C. (2000 degrees F.), but its actual boiling point is about 1400 degrees C. (2550 degrees F.).

BISMUTH BRONZE. Bismuth bronze is an alloy containing 69 per cent of copper, 21 per cent of zinc, 9 per cent of nickel, and 1 per cent of bismuth, with traces of tin. This alloy may be considered as a low-grade German silver.

BIT-BRACE TAPS. As indicated by the name, bit-brace taps are made for use in a bit-brace, and, for this reason, are provided with a square taper shank to fit the socket or jaws of a bit-brace.

BITUMASTIC ENAMEL. Bitumastic enamel is a compound for the preservation of steel against rust in bridges, cranes, roofs, ships, and other structures of iron and steel. Bitumastic enamel was selected by the engineers of the Panama Canal out of three hundred compositions which were submitted to endurance tests, to protect the steel lock-gates and other steel structures used in connection with the canal.

BITUMINOUS COAL. Bituminous coal, generally known as soft coal, contains from 50 to 75 per cent of carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. The heating value per pound of combustible is from 13,500 to 15,500 B.T.U. Coal of this kind gives out large volumes of smoke, and requires special care in firing. The furnaces for burning this coal must be constructed so as to prevent smoke as far as

possible. *Semi-bituminous* coal contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U., per pound of combustible. This coal is softer than the anthracites and has a tendency to produce more smoke, but on account of its high heating value it is one of the best coals for power plant purposes.

BIVALENT. A bivalent is a term used to indicate that an atom of one element combines with two atoms of another element. It is also known as *divalent*.

BLACK DIAMOND. An inferior variety of diamond used in the industries for truing hard grinding wheels. It is more expensive than *bort*, but is more economical to use for hard wheels.

BLACK LEAD. See Plumbago.

BLACK-PRINT. A copy of a drawing similar to a *blueprint*, except that it has black lines on a white background and, therefore, closely resembles an original drawing made with black ink on white paper. Black-prints are used when it is desired to obtain the appearance of an original drawing and when a pleasing presentation of the object represented is the primary consideration. Black-print paper, for making prints having black lines on a white background, is also known as *nigrosine* paper.

BLACK PUTTY. An acid-proof cement made by carefully mixing equal portions of well dried china-clay, gas tar, and linseed oil.

BLACKSMITHS' TAPS. A class of taps known as "blacksmiths' taps" has a long taper thread and a very short shank, the shank being only long enough for a square and a collar to prevent the tap wrench from slipping from the square down upon the body of the tap. The taper of the thread is $\frac{3}{4}$ inch per foot; the size by which the tap is known is measured $\frac{5}{8}$ inch from the large end of the thread. These taps are generally made with the standard number of V-threads per inch corresponding to their nominal diameter.

BLACK WASH. A blackening solution containing carbon applied to large dry-sand and loam cores after baking, to prevent the core sand from burning onto the casting and to assist in parting the core from the surface of the cast iron. The black wash or blackening generally consists of a powder containing graphite or crushed coal or coke in some form. The powder is mixed with clay water, or ordinary water, thus forming a liquid paint which can be applied to the cores with a brush.

BLADES' CONTROLLING DEVICE. A starting device for electric motors, invented in 1888 by H. H. Blades. Motor starters of the hand-operated type are designed on the same principle as the Blades' device.

BLANC FIXE. An artificial form of *barium sulphate*, made by precipitating a barium salt by a soluble sulphate, used in the making of paints for the protection of iron and steel against corrosion.

BLANCHARD LATHE. The Blanchard type of lathe is named after the inventor, Thomas Blanchard, who built the first lathe of this kind in 1822. This machine is designed especially for turning wooden parts of irregular shape, and has been extensively used for turning the stocks of guns and rifles. There is a former or model which corresponds to the shape required. The former is mounted on one side of an oscillating frame which carries on the opposite side the wooden blank to be turned. The former and the blank are rotated at the same speed by gearing, and the turning is done by a rapidly revolving cutter. The cutter is mounted on a carriage and traverses along the bed; at the same time, a wheel which bears against the former or model to be reproduced also moves along with the carriage, and the contact of the model with this wheel causes the frame that supports the work to oscillate in such a way that an accurate copy of the model is turned by the revolving cutter.

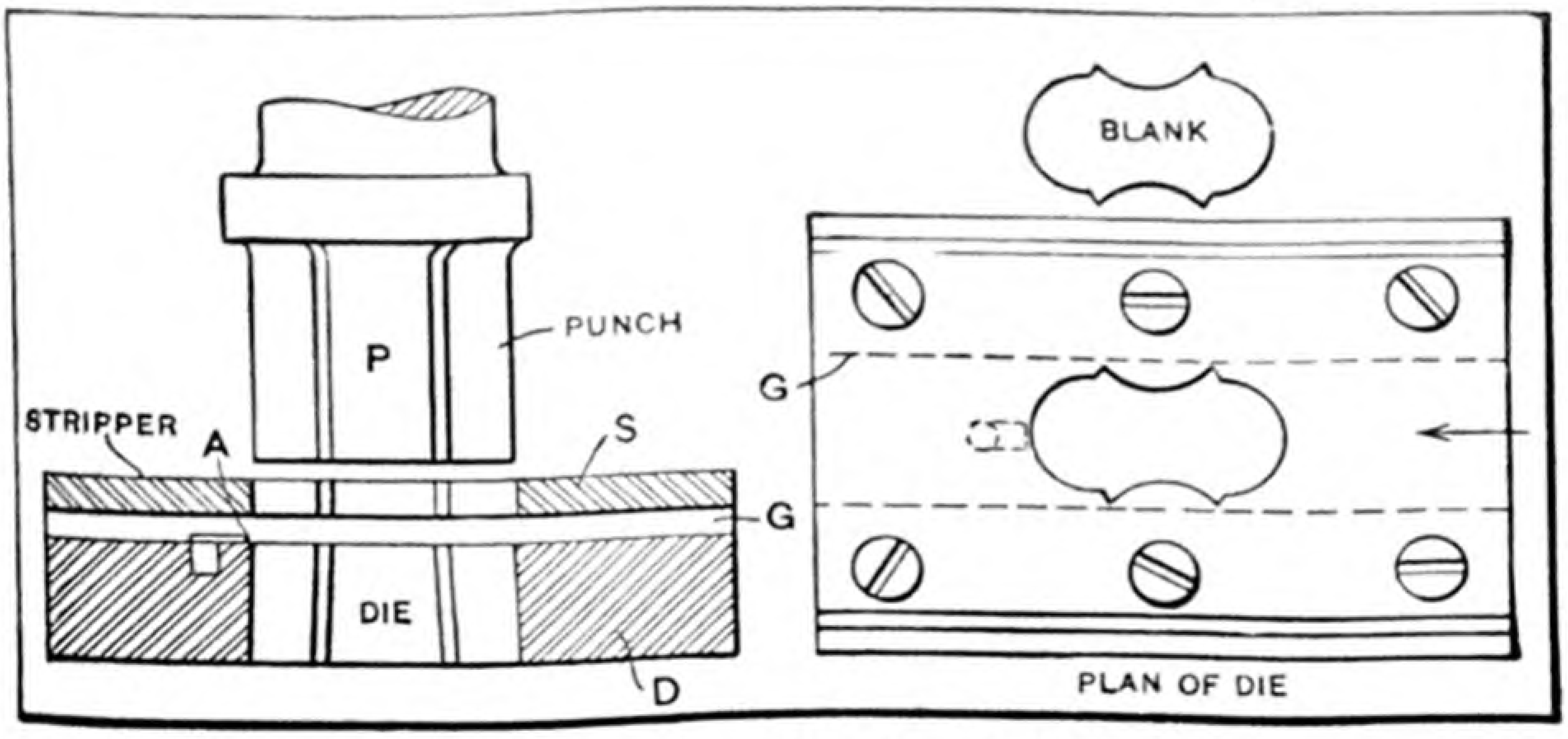
BLANCHED COPPER. Blanched copper is an alloy of copper and arsenic, containing 91 per cent of copper and 9 per cent of arsenic. It is used for clock-dials and for the scales attached to thermometers and barometers. The alloy is made by heating copper strips or chips with white arsenic in an earthenware crucible. The copper and arsenic are laid in alternate layers in the crucible, and the top is covered with common salt.

BLANK DIAMETER. Before making a blanking or drawing die, it is necessary to determine how large the flat blank must be in order to produce a shell or cup of the required form. If the stock did not stretch while being drawn or was not ironed out and made thinner, the diameter of the blank could be determined accurately by calculating the area of the finished article and then making the blank the corresponding area. The kind of metal to be drawn, that is, whether steel, brass, copper, aluminum, etc., and whether it is hard or soft, also affects the size of the blank to some extent.

Owing to the uncertainty of obtaining the right blank diameter by calculation, a common method of procedure, especially when constructing drawing dies for parts requiring more than one or two drawing operations, is to make the drawing part of the die first. The actual blank diameter can then be determined by repeated trials, after which the blanking part of the die may be finished. The blank diameter for a plain cylindrical shell having sharp corners can be determined approximately by the following rule: Multiply the diameter of the finished shell by the height; then multiply the product by 4 and add the result to the square of the finished shell diameter. The square root of the sum thus obtained equals the blank diameter.

BLANK-HOLDER. When a flat blank is drawn either in a combination or double-action die, the outer part is subjected to pressure by a blank-holder; consequently, no wrinkles can form if the die is properly constructed. After the metal has passed from under the blank-holder and over the edge of the die, it is no longer confined and, as it is being drawn into a smaller circumference, the natural tendency is to wrinkle. Such wrinkles are sometimes known as *body wrinkles* to distinguish them from the *flange wrinkles* which result when there is insufficient pressure between the blank-holder and the die.

BLANKING DIES. Dies of the "blanking class" are used for cutting blanks usually from flat sheets or strips of stock; such blanks may or may not be drawn, formed or bent, either by other parts combined with the blanking members, or by means of separate dies. If the chief or only function of



Plain Blanking Punch and Die

the die is to cut blanks, it is a blanking die; if the blanking operation is followed by a more important operation in the same die such as drawing, then the term drawing die would be applied, the blanking part being considered a secondary feature of the design.

Plain blanking dies are the simplest of all types of dies. A blanking die consists essentially of: a die-block such as *D* in the illustration which has an opening that conforms to the shape of the part to be cut or blanked out; a *punch P*, which accurately fits the opening in the die-block and, by a shearing action, does the cutting as it descends into the die-block opening; and a *stripper plate S*, which strips the stock off of the punch-block, as the latter ascends. The opening in the stripper plate conforms to the shape of the punch and is either slightly larger to provide a little clearance, or close fitting to steady the punch. Between the stripper plate and die-block there is a *guide G*, which serves to keep the stock in alignment with the die opening as

it is fed along. A most important point in making blanking dies for odd shapes is to lay them out so that the minimum amount of metal will be converted into scrap.

BLAST FURNACE. Blast furnaces are used for extracting the iron from iron ores; the deoxidation of the iron ore and the removal of the impurities are carried on simultaneously. Carbon, generally in the form of coke, is the deoxidizing agent, although anthracite and charcoal are also used, while limestone is added as a flux to render the slag, as the impurities are called when mixed with the lime and ashes of the fuel, more fusible. The combustion of the deoxidizing agent furnishes the heat necessary to melt the resulting iron and slag. When drawn from the furnace, the iron is run into molds and cast into bars called *pigs*.

The body of a blast furnace is the preliminary heating area for the fuel and ore. It occupies by far the largest proportion of the furnace capacity, from the *bosh* at the bottom, to the *throat* at the top. Generally the sides of the body are slightly tapered, the diameter being larger at the lower end where it joins the bosh and smaller at the top where it joins the throat. The angle of inclination is usually between 3 and 8 degrees. This taper makes it easier for the charge of ore and fuel to descend in the furnace.

BLAST FURNACE FUELS. Charcoal was the principal blast furnace fuel for centuries, and in America it was but natural that it should be used, for timber was plentiful and much of it had to be cut to clear the soil. Both raw coal and coke, however, had been used in Europe for smelting iron ores prior to 1651, but in this country it was not until 1855 that anthracite iron passed charcoal iron in volume of output; in 1869 bituminous fuel also passed charcoal. In 1875, bituminous fuel passed anthracite, and has now become the principal fuel. Beehive coke was used at first but this reached its maximum production in 1916, only to be passed by by-product coke in 1919, and now only one-quarter of the coke used is from beehive ovens. By-product coke making has increased forty fold in twenty-five years.

BLAST FURNACE GAS. The waste gas produced by a blast furnace, containing from 20 to 26 per cent, by weight, of carbonic oxide. It is used for heating the blast, for generating steam, and for operating gas engines. Before the gas can be used in gas engines, however, it must be cooled, the dust washed out, and the gas filtered. The first large blast furnace gas engine was built in 1900. Large steel works develop thousands of horsepower from blast furnace gas.

BLAST FURNACE SLAG. The waste material formed when converting iron ore into pig iron in the blast furnace. The slag is composed of silica,

lime, and alumina, some of these ingredients originating from the ore and fuel, but most of them are from the flux used.

BLEED. A term used in foundry and blast-furnace practice to designate the condition when the metal has solidified on the surface but is not set solid on the inside, so that, if the surface is broken, the molten metal will run out, or "bleed," through the rupture.

BLIND HOLE. In machine construction, a hole which does not pass through a part but has a closed inner end is commonly known as a "blind hole."

BLISTER COPPER. If metallic copper is produced in a furnace by smelting copper sulphide and copper oxide, the resulting product is known as *blister copper*. The name is derived from the fact that the escape of the sulphur dioxide in bubbles gives rise to small cavities or blisters in the mass of the copper.

BLISTER STEEL. Blister steel is produced by the carburization of wrought iron by heating it in a furnace in contact with carbonaceous matter. It is an obsolete method, known as the *cementation process*, and was, in the early days, employed for producing tool steel. After carburizing the carburized bars, called *blister steel*, were then cut up into small pieces and remelted in a crucible, and from that poured into moulds.

BLOCK AND TACKLE. "Block and tackle" is the name given to a hoisting device in which the pull on ropes passing over pulleys or sheaves lifts the load. The pulley, in its simplest form, is a grooved wheel turning within a frame or shell to which a hook, eye, or strap is fastened. The combination of shell, pulley, and hook is known as the *block*, which, by means of the hook, or eye, may be attached to any object. The complete device usually consists of two blocks, one attached to a fixed object and the other supporting the load. The rope connecting the two blocks, and by which they are worked and the load hoisted, is known as the *tackle*. The "pulley" is one of the "mechanical powers." Combinations of pulleys and blocks are used in order to gain a mechanical advantage in raising loads.

BLOCK CHAIN. A "block chain" is a type of chain especially adapted for light machine drives, formed of steel blocks connected by side links or plates. The "B-block" type is so named because the contour of the blocks resembles somewhat the letter "B." There is also what is known as the "figure-8" block which has blocks that are rounded out between the ends on both sides so that the contour resembles the figure 8. A block chain of the double width form is used when the amount of power to be transmitted is relatively high.

BLOCK INDEXING. With the multiple or "block" system of indexing, which is sometimes used in gear-cutting, a number of teeth are indexed at one time instead of cutting the teeth consecutively, and the gear is revolved several times before the teeth are all finished, For example, when cutting a gear having twenty-five teeth, the indexing mechanism is geared to index four teeth at once, and, the first time around, six widely separated tooth spaces are cut. The second time around, the cutter is one tooth behind the spaces previously milled. On the third indexing, the cutter has dropped back another tooth, and the gear is finished (in this case) by indexing it around four times. The object of this method is to distribute the heat generated by the cutter (especially when cutting cast-iron gears of coarse pitch) more evenly about the rim of the gear, thus avoiding distortion due to local heating, and permitting higher speeds and feeds.

BLOOD-ALBUMIN GLUE. See Glues for Wood.

BLOODSTONE. A natural stone of small size sometimes used for burnishing small round work in the lathe. The bloodstone is mounted in a steel holder. It is an expensive tool, but ordinarily lasts for years.

BLOOM. The products of a rolling mill may be classed as semi-finished and finished. In the first class are blooms, slabs, billets, and sheet bars which have square, rhomboidal, or flat sections with rounded corners. A *bloom* has a square section and is about 6 inches square or larger.

BLOOMING MILL. See under Rolling Mills.

BLOWER. A blower may be defined as a low-pressure air compressor adapted for use in connection with forges, cupolas, gas plants, and blast furnaces. Blowers or compressors for this purpose are required to furnish air under pressures usually ranging from about two ounces to thirty pounds per square inch.

A *steel pressure fan or blower* is a special form of the ordinary ventilating fan adapted to higher pressures. The standard makes are commonly built for working pressures up to a maximum of about one pound per square inch, although special types may be constructed for considerably higher pressures. Blowers of this type are employed principally for forge and cupola practice. A *centrifugal blower* operates on the same principle as the pressure fan, but is designed for maintaining pressures up to from three to four pounds per square inch, thus considerably extending its field of operation beyond that of the steel pressure blower. A *rotary or positive pressure blower* is not a fan, although it is used for similar purposes. It is positive in its action and operates by displacement, the same as a piston compressor, although it is radically different in its construction. The maximum working pressure, with this type of blower, is limited to about ten pounds per square inch;

and some of the standard makes of this type are not built for pressures exceeding five pounds per square inch. They are employed for purposes where a higher pressure is required than that which can be obtained economically by means of a centrifugal blower; but the uses to which these two types are put, overlap one another to some extent. *Rotary blowers* have a wide field of application, being used for furnishing blast for cupolas, gas and oil burners, annealing and smelting furnaces, puddle furnaces, forges, gas plants, etc., as well as for vacuum cleaning, ash conveyors, pneumatic tube service, and many other special uses. When pressures exceeding those economically produced by the centrifugal and rotary blowers are required, and, in some cases, for service for which these latter blowers could be used, the centrifugal compressor is employed, commonly known as the *turbo-compressor.*

BLOWER, GAS ENGINE. The advantage of the gas engine over steam for blower work relates chiefly to the saving in fuel gas and to the elimination of the boiler plant, in so far as it is required for this purpose alone. On the other hand, gas engines lack the flexibility of steam in case of emergencies. They have but little, if any, overload capacity, making it necessary to operate them at as nearly full load conditions as possible, and vary the power output by changing the number of units in use. Owing, however, to their greater thermal efficiency, gas engine blowers have been installed in some of the largest plants in the country. The type commonly adopted is double-acting, having a long piston which covers the exhaust ports, which are located at the center of the cylinder, until near the end of the stroke, thus doing away with exhaust valves and simplifying the construction. Air and gas are forced into the cylinder in the right proportions by means of separate pumps.

Efficiency. — The usual form of two-cycle engine has a mechanical efficiency ranging from 75 to 80 per cent, this comparatively low figure being due to the power required for operating the air and gas pumps. While the four-cycle engine has a slightly higher efficiency, it is offset to a considerable extent by the more complex valve gear.

Capacity. — When supplied with blast furnace gas giving a mean effective pressure of 60 to 70 pounds per square inch, a cylinder 38 by 60 inches will develop 1000 brake horsepower at 75 to 80 revolutions per minute. Under these conditions an engine of the above dimensions could deliver approximately 20,000 cubic feet of air per minute at a pressure of 15 pounds, or 14,000 cubic feet at 25 pounds.

BLOWER PRESSURES. The pressure used in connection with blower work is of three kinds, known as *dynamic*, *static*, and *velocity* pressure. The dynamic pressure is that due to the momentum of the air as it leaves the fan discharge, and acts only in the direction of flow. The static pressure is that

produced by placing a resistance in the path of the air current, and, when confined in a duct, causes a uniform pressure in all directions, the same as the steam pressure within a boiler. It is evident that the dynamic pressure tends to drive the air through the fan outlet, while the static pressure tends to hold it back. The difference between these is called the velocity pressure, and is the working pressure which actually forces the air through the discharge opening in the casing. The relation between the velocity pressure and the velocity of flow which it produces, for air at a temperature of 60 degrees F., is expressed very nearly by the formula:

$$v = 66\sqrt{h},$$

in which, v = velocity of flow, in feet per second; h = velocity pressure, expressed in inches of water column. Ounces per square inch may be reduced to inches of water column by multiplying by 1.73, and inches of water column may be changed to ounces per square inch by multiplying by 0.58.

BLOW, FORCE OF. See Force of Blow.

BLOW-HOLES IN CASTINGS. Blow-holes are the result of an outrush of gas from the core or mold materials into the molten iron, at the time of solidification. If the solidification has proceeded so far that the outrushing gas or steam cannot bubble through it and escape through the vents which should be provided for the purpose, it will be imprisoned in the casting, forming one or more holes, according to the shape of the casting and the quantity of the escaping gas. These holes may not be apparent on the outside, and quite often occur in a location where they do no particular harm, but they are frequently located at some point where they are unsightly or greatly weaken the casting.

BLOWING ENGINE. The term "blowing engine" is commonly used to designate blowers of the piston or reciprocating type used in connection with blast furnaces. These machines are simply air compressors designed for large volumes of air at comparatively low pressures. While superseded to a certain extent by the centrifugal compressor, blowing engines are still used in some of the largest plants in the country. Both steam and gas engines are employed for driving blowers.

BLOWN OR THICKENED OIL. A class of fixed oils (usually rape or cottonseed) which are artificially thickened by forcing a current of air through them when heated. This process increases the density and viscosity. Blown oils mixed with mineral oils are very largely used as lubricants. The mineral oils used for this purpose are usually of rather low viscosity.

BLOW-OUT CIRCUIT-BREAKER. A device for automatically opening an electric circuit, so constructed that, when it opens under load, the result-

ing arc is instantly extinguished as the secondary contacts are parted, due to the force of a strong magnetic field automatically set up in the iron circuit of the blow-out magnet by the current being shunted through the blow-out coils and the secondary contact when the main brush breaks contact. The secondary contacts break contact immediately afterwards.

BLUE GLASS. Blue glass is a development of the Bureau of Standards for protecting the eyes of furnace workers. This glass provides good contrast between the appearance of the furnace walls and the melt, and yet eliminates the dangerous ultraviolet radiation.

BLUE METAL. An impure copper sulphide, containing some iron, which is obtained when smelting copper ores. When copper and some copper oxide are present the term "purple metal" is used.

BLUEPRINTING. Blueprinting is a process of making copies of drawings that are made on transparent paper or tracing cloth. The tracing is used in a manner similar to that of the negative in making photographic prints, except that the tracing is a "positive," and the blueprints are negatives. The tracing with blueprint paper held tightly beneath it is exposed to the sunlight from 3 to 10 minutes, according to the intensity of light, or exposed to the brilliant electric lights in a blue printing machine. After the exposure, the paper is washed thoroughly in cold water for about ten minutes and then hung up to dry. The print should show a deep blue color after washing and the lines should be clear white. If the color is pale blue, the print has not been exposed to the light for a sufficient length of time. If the lines of the drawing are not clear and white, the print has been over-exposed. An over-exposed blueprint can be improved upon by pouring a little of a solution made from one teaspoonful of *bichromate of potash* dissolved in one-half gallon of water, over the print while it is in the sink. The print must then be again washed with water before it is hung up to dry. The bichromate of potash solution will improve the appearance even of blueprints that have not been over-exposed.

BLUEPRINTING MACHINES. When a large number of blueprints are to be made, blueprinting machines are used for making prints without the aid of sunlight. These machines are generally provided with brilliant electric light, making it possible to produce prints at any time of the day or night.

The blueprint paper with tracings on top is passed by the light at a given rate of speed, which speed may be adjusted according to the requirements. Some machines are provided with an apparatus for washing and drying the prints after exposure.

BLUEPRINT MARKING INK. Ordinary red writing ink with a little sal soda added will give clear distinct marks on blueprints. Very little sal

soda is needed. Different grades of ink require different amounts, the right mixture being determined by adding the soda, a few grains at a time, until the ink begins to spread the least bit as it dries. A bright vermillion can be produced, which has the advantage of being visible as soon as it is placed on the blueprint.

BLUE VITRIOL. The commercial name applied to copper sulphate.

BOARD DROP-HAMMER. See under Drop-hammers.

BOARD MEASURE. Board measure, as employed for measuring lumber, is based on the assumption that all boards are 1 inch thick. In order to obtain the number of feet board measure, multiply the length in feet, the width in feet, and the thickness in inches. For example, a board 2 inches thick, 10 feet long, and 9 inches wide would equal $10 \times \frac{3}{4} \times 2 = 15$ feet board measure. Board measure is frequently abbreviated B.M.

BOARD MEASURE OF LOGS. See Doyle Rule; Moore & Beeman Rule; Scribner Rule; St. Croix Rule.

BOB-WEIGHT. When reciprocating and revolving parts are connected and operated together, as in the case of a steam engine, only partial balance may be obtained by the use of a rotating counterbalance. In attempting to secure more perfect balance, what is known as a "bob-weight" has been used, though rarely. This bob-weight, as applied to a single-cylinder engine for the purpose of balancing the reciprocating parts, consists of another reciprocating part or weight operated by an eccentric in order to counteract the lack of balance in the reciprocating masses.

BOILER CARE DURING IDLE PERIOD. At the time boilers are to be taken out of service, it is often desirable to remove the accumulated scale and then to adopt some means of preserving the boiler against deterioration during the interval of rest. A method that has proven satisfactory is to fill the boiler nearly full with water, add two or three pailsful of soda ash and with a slow fire carry 5 to 10 pounds pressure for about 24 hours. Then wash out the boiler, clean the fittings and connections and repeat the boiling off and washing until the scale is removed. After cleaning, if the boiler is to stand ready for use at short notice, fill it completely with clean water and at firing-up time draw off the water to the proper working level; otherwise dry the boiler out and allow it to stand empty and closed up tight. Then before starting-up time it will be in best condition for removal of any scale that has to be dislodged by scraping or chipping.

BOILER CODE. This term is generally understood to refer to the rules and specifications for the construction of steam boilers and other pressure vessels, adopted by the American Society of Mechanical Engineers.

BOILER EFFICIENCY. The ratio of the heat utilized in the process of evaporation to the total heat of the fuel burned in a steam boiler; this ratio makes possible a comparison between the amount of steam evaporated and the amount of fuel consumed.

BOILER FEED PUMPS. Direct-acting steam pumps for boiler feeding are frequently used, but are wasteful in the use of steam; if the exhaust can be used for feed-water heating, this is, however, not of so much importance. On the other hand, they are easily regulated to furnish the required amount of feed water under varying conditions, and are extensively used for this purpose. The ratio of the diameter of steam to water cylinders is commonly made about 1.25, this surplus area being sufficient to overcome any usual friction in the pump and piping, and to force the water into the boiler. Steam pumps for boiler feeding are commonly rated at the boiler horsepower which they will supply at different rates of speed. When the temperature of the water to be handled is over 190 degrees F., it should flow to the pump by gravity, as it is likely to break into steam if an attempt is made to lift it by suction. *Centrifugal feed-pumps* driven by steam turbines, and *Injectors* are also used for boiler feeding.

BOILER FEED-WATER HARDNESS. Hardness of boiler feed water is a condition caused by the presence of the incrusting solids, such as carbonates, sulphates, chlorides, and nitrates of lime and magnesia. The degree of hardness is a measure of the quantity of incrusting solids which boiler feed waters contain per gallon. The hardness may be temporary or permanent. *Temporary* hardness is caused by carbonates, and *permanent* hardness by sulphates, chlorides, and nitrates.

BOILER FEED-WATER HEATERS. Feed-water heaters are divided into two general classes known as open heaters and closed heaters. In the *open heater*, the steam and water mingle in the same chamber, and the water is heated by direct contact with the steam, which is condensed and mixes with the water. A common form of open heater, which is designed to act as a purifier, filter, and receiver, is so arranged that the water to be heated enters the heater at the top and falls in small streams over a series of trays or pans suspended in the steam chamber. One advantage of the open heater over the closed is that the water may be heated to the maximum temperature regardless of the cleanliness of the interior surfaces. When considered as a purifier, the accumulation of mud and scale beyond a certain point has a decided effect upon its efficiency. In the *closed heater* the water passes through a series of brass or copper tubes which are surrounded by steam, there being no intermingling of the water and steam. The open heater must necessarily be on the suction side of the boiler feed-pumps whereas the closed heater should be on the discharge side, where the friction loss can be supplied

by the pumps. Feed-water heaters are usually rated in horsepower. The term " horsepower," in this case, is purely an arbitrary one, and commonly supposed to mean the heating of 30 pounds of water per hour from 50 degrees to 212 degrees F., or the input of about 5000 B.T.U. per hour.

BOILER FEED-WATER HEATING. Boiler feed water is usually heated before discharging it into the boilers for two reasons: First, to overcome the effect of a rapid cooling of the plates which is likely to result in unequal contraction and the formation of leaks at the joints, and also because a considerable volume of cold water fed into a boiler tends to reduce the steam pressure and thus makes it necessary to force the furnace for a time after feeding. Second, because feed-water heaters are nearly always arranged to utilize the waste gases from the furnace or the exhaust steam from the engines, and thus a considerable saving in fuel may be realized by their use.

The percentage of saving in fuel by the use of a feed-water heater may be obtained approximately by dividing the total rise in temperature by 11. For example, if the water enters the heater at a temperature of 50 degrees F. and leaves it at 200 degrees F., the total rise is $200 - 50 = 150$ degrees, and the percentage of saving is $150 \div 11 = 13.6$. The proportion of the heat in the steam generated by the boiler, which is utilized in heating the feed water, may be found as follows: If it is assumed that the water is to be raised from 50 to 210 degrees F., the heat absorbed by 1 pound will be $210 - 50 = 160$ B.T.U. The latent heat of steam at atmospheric pressure is 966 B.T.U.; hence $160 \div 966$ of the heat in each pound of exhaust steam is utilized in heating the feed water. This proportion is approximately one-sixth.

BOILER FEED-WATER IMPURITIES. Pure water is a chemical compound made up of two parts of hydrogen and one part of oxygen, by volume, and weighs 62.4 pounds per cubic foot at a temperature of 62 degrees F. It is never found in a pure state under natural conditions, as it absorbs large quantities of various impurities in its passage through the air, and in filtering through the earth before it reaches the wells or streams from which it is drawn for use in boiler plants or for other purposes. The impurities commonly found in boiler feed water may be classed under three heads, as follows: 1. Those causing the formation of scale; these impurities include calcium carbonate, calcium sulphate, magnesium carbonate, and magnesium sulphate. 2. Those having a corrosive action, such as sulphuric acid, carbonic acid, magnesium chloride, calcium chloride, and sulphate of iron. 3. Alkaline impurities which include sodium carbonate, sodium sulphate, sodium chloride, potassium carbonate, potassium sulphate, and potassium chloride. In addition to the impurities mentioned, various substances are held in suspension, such as organic matter, mud and oil.

Feed-water Filters. — As applied to steam boiler operation a filter is a device used for the purification of boiler feed water. A filter is employed especially for river water which may contain fine sand or other fine particles which would readily pass through a fine strainer or remain suspended in the water, even when left to settle in a settling tank. The filter materials are usually porous materials, such as crushed quartz, coke, charcoal, excelsior, and burlap.

BOILER FEED-WATER, OIL TEST. In cases where the condensation from an exhaust steam heating system is returned to the boilers, it is often desirable to test the water for oil to see if the separators are working satisfactorily. In making this test, a sample of the water is cooled, and 250 cubic centimeters are placed in a separating funnel with 25 cubic centimeters of ether, and thoroughly shaken. The funnel is then placed in an upright position and allowed to stand for fifteen or twenty minutes, after which the water is drawn off by means of the separating cock at the bottom. The ether solution floating on the water, which contains all of the oil, is placed in a porcelain dish and evaporated over a water bath heated by steam. No open flame should be allowed in the room, as the ether vapor is very inflammable. The solution evaporates quickly, leaving any oil which may be present in the bottom of the dish. It is not usually customary to measure the oil thus found, as any amount detected in this manner is undesirable.

BOILER FEED-WATER PURIFICATION. The methods employed for the purification of feed water may be classed under three general heads as follows: 1. By filtering. 2. By heat. 3. By the use of chemicals. The character of the water will indicate whether one or more of these processes must be resorted to. Purification by mechanical means is employed only where the impurities are suspended in the water, as mud, sand, oil, vegetable matter, sewage, etc., and may be accomplished in three ways according to the substances present, and the available space for the apparatus. The methods commonly employed for this purpose are: Settling in large tanks; filtration; and skimming. Water from streams containing sawdust, chips, sticks, etc., requires simply a strainer over the suction pipe to the pump, if no other impurities are present.

BOILER FEED-WATER REGULATOR. This is a device used in connection with steam boilers for automatically regulating the height of the water line. A simple device makes use of a float connected by means of levers to a pilot valve which admits steam pressure to, or exhausts it from, a diaphragm which controls the feed valve of the boiler.

BOILER HEATING SURFACE. The *heating surface* of a boiler is commonly defined as that portion having one side of the plates or tubes exposed

to the hot gases and the other in contact with the water. When computing the heating surface, it is more common to take the fire surface rather than the water surface. The capacity of a boiler depends not only upon the amount of heating surface, but on its arrangement as well.

BOILER HORSEPOWER. The horsepower rating of a boiler is an arbitrary one and should not be confused with the horsepower unit of power representing 33,000 foot-pounds per minute. The standard boiler horsepower in the United States is the capacity to evaporate 30 pounds of water per hour from a feed-water temperature of 100 degrees F. into dry steam at 70 pounds gage pressure. This is equivalent to the evaporation of 34.5 pounds of water from a temperature of 212 degrees F. into steam at atmospheric pressure, which corresponds to a zero gage reading. Under ordinary conditions a boiler can be operated at 50 per cent over-rating at normal load and 100 per cent over-rating on peaks; the latter value means 69 pounds of steam per rated boiler horsepower instead of $34\frac{1}{2}$. But 69 pounds from and at 212 degrees F. must be corrected for the pressure to be used and the temperature of the feed water. For general calculations, it is customary to figure a boiler horsepower at 30 pounds, and then add the percentage over-rating at which the boiler is expected to operate.

BOILER JOINT EFFICIENCY. The efficiency of a joint is the ratio which the strength of the joint bears to the strength of the solid plate. In the case of a riveted joint this is determined by calculating the breaking strength of a unit section of the joint, considering each possible mode of failure separately, and dividing the lowest result by the breaking strength of the solid plate of a length equal to that of the section considered.

BOILER PATCH BOLT. See Patch Bolt.

BOILER RATE OF COMBUSTION. See Rate of Combustion for Boilers.

BOILER RATING. The rating of a steam boiler is a measure of its capacity given either in square feet of heating surface or in boiler horsepower. In horizontal fire-tube boilers, it is customary to allow 12 square feet of heating surface per boiler horsepower for power boilers, and 15 square feet for heating boilers. Water-tube boilers are rated on a basis of 10 square feet of heating surface per boiler horsepower.

BOILER SCALE. The scale or incrustation formed in a boiler may be due to the precipitation of mineral substances or by the settling of mud or earthy matter held in suspension by the feed water. When the water is exceptionally bad, purifiers are often used, the water passing through the purifier before it enters the boiler. In this purifier, the temperature is

raised until the water will no longer hold the carbonates and sulphates in solution, these being the most troublesome scale-forming substances; therefore, they are precipitated and remain in the purifier instead of being forced into the boiler. Various chemical substances are also introduced into boilers to combine with and dissolve the scale-forming material. One of the cheapest and most effective of these substances is carbonate of soda. It is effective in preventing and removing scale resulting from both the carbonate and sulphate of lime. The best method is to connect the feed pump or injector to a soda tank so that at regular intervals a supply of soda can be introduced into the boiler. The proper amount should be determined in each case by experiment, and usually varies between one and two pounds per day for an average boiler. The lowest quantity that is effective should be used; if too much soda is used, it is apt to cause *priming*. The soda does not injure the boiler unless it is impure and contains acids.

Among the many substances introduced into boilers with the object of preventing the scale from forming into a hard mass, may be mentioned kerosene oil and petroleum. The former is generally considered preferable. It is claimed by those who have used kerosene that one quart per day for each 100 horsepower is sufficient to prevent the formation of scale, even though the water is very hard and impure. Kerosene is also effective for breaking up and loosening hard scale after it has formed. The most certain and effective remedy for the removal of scale which has been deposited on a boiler is by mechanical means, although chipping and scraping off the scale is often difficult and sometimes impossible, owing to the lack of room. The best method is to prevent the formation of the hard scale, and the easiest way of removing impurities is by opening the blow-off valve occasionally. A large part of the scale is naturally carried to the coolest part of the boiler (to the mud drum, if there is one), and it may be removed by blowing off the boiler while under steam pressure. The fact that many impurities are held in suspension and float as a scum on the water for some time before settling, has led to the use of the surface blow-out apparatus.

BOILERS, FIRE-TUBE. Boilers of the fire-tube type are so designed that the hot gases pass through the tubes which are enclosed in a shell and surrounded with water. The horizontal return tubular boiler is the most common form of fire-tube boiler, although the vertical form is sometimes used where floor space is limited. Certain makes of internally fired boilers are also constructed with fire tubes, as are also the usual types of marine and locomotive boilers. The horizontal tubular boiler is extensively used for heating, and, to a considerable extent, for power work. Some of the advantages claimed for the fire-tube type of boiler are its low first cost, large water capacity, and its simplicity of construction.

BOILERS, WATER-TUBE. Water-tube boilers are so named because the water is inside the tubes, which are surrounded by the hot gases. This gives a more rapid circulation to the water, which increases the efficiency of the heating surface. In addition, the large amount of surface exposed directly to the fire increases the transmission of heat and prevents overheating. The draft area, sometimes constricted in fire-tube boilers, is always ample in this form, which gives a slower movement to the gases and allows more time for the absorption of their heat by the water. Other advantages are the rapidity with which steam may be raised, owing to the water being divided into a large number of small streams which pass through the hottest part of the fire, and also the safety due to the same cause, the division of the water into small masses preventing serious results in case of rupture. Water-tube boilers are made both horizontal and vertical in form, the tubes in the former being inclined upward toward the front in order to assist in the circulation. When properly constructed, the different surfaces are easily reached for cleaning, and being made up of comparatively small parts, are easily transported and erected. The principal disadvantage is the small amount of water space, which limits the reserve capacity in case of sudden calls for steam.

BOILER TAPS. There are two kinds of boiler taps, straight and taper. *Straight boiler taps* are only a special class of hand taps. They have a long chamfer or taper on the top of the thread and a straight guide at the end or point. The chamfered portion is relieved on the top of the thread. They are fluted in the same manner as hand taps. *Taper boiler taps* are used in steam boiler work, and, like the pipe tap, are used where a steam-tight fit is desired. The taper of these taps is $\frac{3}{4}$ inch per foot. The size by which the taps are known is measured $\frac{1}{4}$ inch from the large end of the thread.

BOILER TESTING. The tests most commonly made on steam boilers are for *steaming capacity* and *efficiency*. The power, or steaming capacity, of a boiler depends upon the weight of dry steam which it will evaporate in a given time, without regard to the weight of fuel required. The efficiency takes into account the fuel consumption as well as the amount of steam evaporated, and is the ratio of the heat utilized in the process of evaporation to the total heat in the fuel burned. In comparing two boilers, the weight of dry steam in each case is reduced to an equivalent evaporation from and at 212 degrees F., the quality of the steam being determined by the use of a *calorimeter*. The efficiency of the boilers should be given due weight in making a comparison.

BOILER TUBE SPECIFICATIONS. The following specifications for lap-welded and seamless boiler tubes have been approved by the Boiler Tube Manufacturers of America. Lap-welded tubes shall be made of open-hearth

steel or knobbled hammered charcoal iron. Seamless tubes shall be made of open-hearth steel. The steel shall conform to the following requirements as to chemical composition: Carbon, from 0.08 to 0.18 per cent; magnanese, from 0.30 to 0.50 per cent; phosphorus, not over 0.04 per cent; and sulphur, not over 0.045 per cent.

Tubes for Water-tube Boilers. — According to the A.S.M.E. "Boiler Code," the minimum thickness of tubes used in water-tube boilers, measured by the Birmingham wire gage, for maximum allowable working pressures not exceeding 165 pounds per square inch, shall be as follows: Diameters less than 3 inches, No. 12 B.W.G.; 3 inches or over but less than 4 inches, No. 11 B.W.G.; 4 inches or over but less than 5 inches, No. 10 B.W.G.; 5 inches, No. 9 B.W.G. The foregoing gages shall be increased as follows for maximum allowable working pressures higher than 165 pounds per square inch: Over 165 pounds but not exceeding 235 pounds, 1 gage; over 235 pounds but not exceeding 285 pounds, 2 gages; over 285 pounds but not exceeding 400 pounds, 3 gages. Tubes over 4 inches in diameter shall not be used for maximum allowable working pressures above 285 pounds per square inch.

Tubes for Fire-tube Boilers. — The minimum thickness of tubes used in fire-tube boilers, measured by the Birmingham wire gage, for maximum allowable working pressures not exceeding 175 pounds per square inch, shall be as follows: Diameters less than $2\frac{1}{2}$ inches, No. 13 B.W.G.; $2\frac{1}{2}$ inches or over but less than $3\frac{1}{4}$ inches, No. 12 B.W.G.; $3\frac{1}{4}$ inches or over but less than 4 inches, No. 11 B.W.G.; 4 inches or over but less than 5 inches, No. 10 B.W.G.; 5 inches, No. 9 B.W.G. For higher maximum allowable working pressures than previously given, the thickness shall be increased one gage.

BOILING POINT. The boiling point of a substance is the temperature at which it changes from a fluid to a gaseous form, under atmospheric pressure (14.7 pounds per square inch). The boiling point of water is 100 degrees C. (212 degrees F.). In order to cause the transformation from a fluid to a gaseous form, a certain amount of heat, known as the *latent heat of evaporation*, must be supplied to the liquid at the boiling point.

BOLSTER. Dies are usually held in position on the bed of a punch-press by means of a *bolster* or *diebed*, although large dies are often attached directly to the press bed. The principal functions of a bolster are: 1. That of supplying an adequate support for the die, and a holder to hold the die in its proper position to be engaged by the punch. 2. To furnish a means of attachment to the press. Bolsters are commonly made of cast iron, cast steel, or machine steel. Large manufacturers seem to favor the use of semi-steel castings, or machine steel, rather than cast iron, for bolsters for certain classes of heavy work.

BOLT AND NUT STANDARDS. See Nut Standardization.

BOLT CUTTERS. The machines used for cutting the threads on bolts are known as "bolt cutters." A typical design is called a *single* bolt cutter because it has one spindle. Some bolt cutters have two, three, or four spindles and are known as *double*, *triple*, and *quadruple* bolt cutters, respectively. The thread is cut by means of a die-head attached to and revolved by the spindle of the machine. The bolt cutters having two or more spindles are used in preference to the single-spindle type where large quantities of bolts are to be threaded constantly. These machines operate on the same general principle as the single-spindle design. The spindles are parallel and each one has an independent carriage and vise so that, while a thread is being cut on one bolt, another bolt is being inserted in or removed from the vise of another carriage.

Some bolt cutters are equipped with a lead-screw so that the carriage will have a positive feeding movement when a thread is being cut, in order to prevent inaccuracy in the pitch of the thread. When a bolt cutter does not have a lead-screw, the feeding movement of the carriage is derived from the action of the dies upon the thread being cut. This method of feeding is satisfactory when cutting such threads as the United States Standard, the V-thread, or a Whitworth thread. When cutting square threads, however, or those of special form, or when threading long work where the cumulative error becomes important, a lead-screw is necessary.

BOLT, EXPANSION. See Expansion Bolt.

BOLT FORGING MACHINES. Upsetting and heading machines of modern design are divided into two general classes: stop-motion and continuous-motion headers. The stop-motion headers have the greatest range, and are primarily used for heading bolts, but are also used for all kinds of upset forgings. The continuous-motion headers are used only for heading rivets, carriage bolts, and short lengths of hexagon- and square-head machine bolts; they produce these parts at a much faster rate than is possible with a stop-motion header, but their range of work is limited.

BOLT FORGING, ORIGIN. The bolt and nut industry in America was started in a very small way in Marion, Conn., in 1818. In that year Micah Rugg, a country blacksmith, made bolts by the forging process. The first machine used for this purpose was a device known as a heading block, which was operated by a foot treadle and a connecting lever. The connecting lever held the blank while it was being driven down into the impression in the heading block by a hammer. The square iron from which the bolt was made was first rounded, so that it could be admitted into the block. At first Rugg only made bolts to order, and charged at the rate of sixteen cents apiece. This industry developed very slowly until 1839, when Rugg went into partnership with Martin Barnes; together they built the first exclusive bolt and nut fac-

tory in the United States in Marion, Conn. The bolt and nut industry was started in England in 1838 by Thomas Oliver, of Darlston, Staffordshire. His machine was built on a somewhat different plan from that of Rugg's, but no doubt was a further development of the first machine; Oliver's machine was known as the "English Oliver."

BOLT HEAD STANDARDS. According to the U. S. Standard, bolt heads have the same width across the flats as nuts for the same bolt sizes. Although many nuts used at the present time conform to the U. S. Standard, this is not true of bolt heads.

According to the American Standard for Rough and Semi-finish Square and Hexagonal Regular Bolt Heads, the width across the flats equals $1\frac{1}{2}$ times the bolt diameter, with adjustments in the sixteenth-inch sizes to eliminate widths to thirty-seconds of an inch. The tolerance for widths across flats is minus 0.050 times bolt diameter. For American Standard Finished Square and Hexagonal Bolt Heads, the widths across the flats equal $1\frac{1}{2}$ times bolt diameter, excepting the bolt diameters from $\frac{1}{4}$ to $\frac{9}{16}$ inch inclusive, which have widths across the flats equal to $1\frac{1}{2}$ times bolt diameter plus $\frac{1}{16}$, with adjustments in the sixteenth-inch sizes to eliminate widths to thirty-seconds inch. The tolerances for finished heads are minus 0.015 times bolt diameter, plus 0.006. See also Nut Standardization.

BOLT OIL. This is a viscous neutral oil used for thread cutting. It has a gravity of about 30 degrees Baumé and a viscosity of about 220.

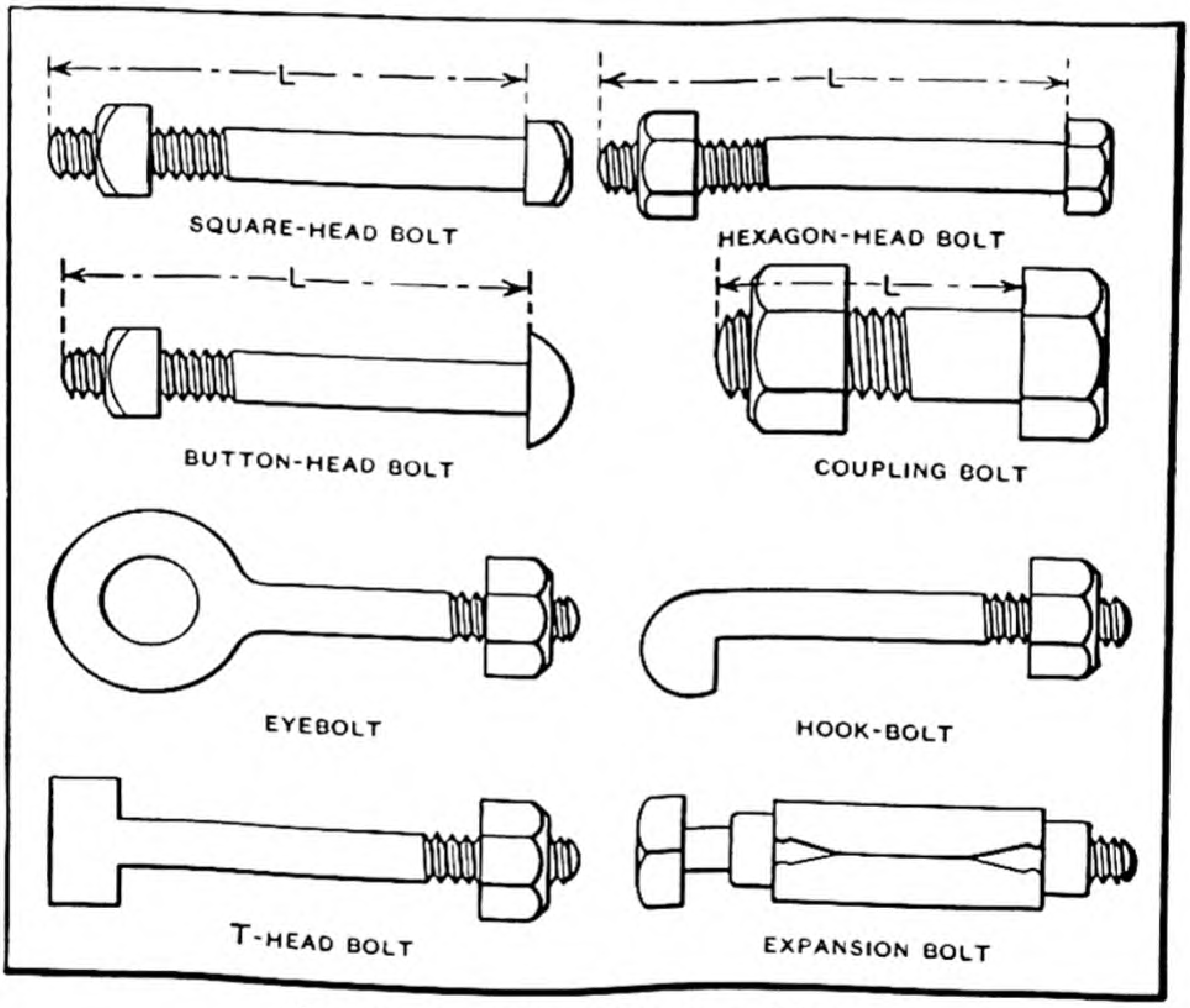
BOLT-POINTING MACHINES. The "bolt pointer" is a machine used for rounding or pointing the ends of bolts preparatory to cutting the thread. As the bolt leaves the "header" or machine which forms the head, the ends are generally irregular, resulting from the action of the shear in cutting the stock; this irregular edge makes it difficult to start the thread cutting die, so ordinarily a pointing tool is used which is so formed as to produce a rounding end. These pointing machines have a spindle which carries the cutter head, and a vise for holding the bolt to be pointed.

BOLTS. The difference between a bolt and a screw, according to the generally accepted meaning of the terms, is that nuts are used on bolts, whereas screws are inserted into tapped holes; there are exceptions, however, to this general classification. A bolt has a solid head on one end and ordinarily one or two nuts on the other, which bind together whatever parts are to be held. A bolt may pass through a "clearance hole" or one that is slightly larger than the bolt diameter, or it may be accurately fitted to the hole so that the body of the bolt will prevent lateral movement of the parts instead of relying entirely upon the friction resulting from the pressure of the nut. The illustration shows standard bolts with the several types of heads and some special forms of bolts.

Eyebolt. — The eyebolt is so named because the head forms a loop or "eye" which may be used in different ways. Eyebolts are often attached to heavy machine parts to provide means for lifting them when making repairs, etc., the eye of the bolt being engaged by the hook of a crane or hoist.

Hook-bolt. — The hook-bolt is a special form of bolt having a hook-shaped head instead of one that is square or hexagonal. Such a bolt may be used when the part to be clamped is too narrow for drilling a bolt hole through it, or because such a hole would weaken the part excessively.

T-head Bolt. — The T-head bolt is extensively used for clamping castings and forgings to various kinds of machine tools. The T-shaped heads of the bolts engage T-slots which extend along the table of the machine.



Standard and Special Forms of Bolts

Expansion Bolt. — When a through bolt cannot be used for attaching a pipe hanger, bracket, or other part, to a wall or ceiling of brick or concrete, what are known as *expansion* bolts are often used. The body of an expansion bolt is divided and the arrangement is such that, when the head of the bolt is turned, the sections forming the body of the bolt are forced outward and against the wall of the hole which has been drilled into the brick, concrete, or stone, as the case may be. Bolts of this type are made in quite a variety of designs. The nominal size represents the diameter of the bolt proper and not the diameter of the casing or expansion member.

BOLT STRESSES. The initial tensional stress in a tightened bolt or stud holding a part subjected to pressure may or may not be increased by that pressure before the initial tension of the bolt is exceeded. When bolts are more elastic than the material compressed, as when flanges are bolted together without a yielding packing between, the stress in the bolts equals either the initial stress (due to tightening the nut) or the force applied, depending upon which is greater. If the material compressed is more elastic than the bolts, as when an elastic packing is compressed between flanges, the stress in the bolts equals the initial stress plus the force applied.

BOMB CALORIMETER. One of the most commonly used devices for determining the heating value of fuels. See Calorimeter.

BONDING PROCESSES FOR GRINDING WHEELS. By the use of different abrasives, grinding wheels can be produced which are adapted to many different purposes. The important properties of an abrasive are hardness, toughness, absence of impurities, uniformity, and fracture or sharpness. The nature or characteristics of a grinding wheel can also be changed by using different bonds, the bond being the adhesive substance which holds the abrasive grains together in the form of a wheel. The three most important bonding processes are known as the vitrified, silicate, and elastic processes, and these names are applied to the wheels. For instance, a wheel made by the vitrified process is commonly referred to as a vitrified wheel, etc. Among other processes which are occasionally employed may be mentioned the rubber or vulcanite process, the celluloid process, and the oil process.

In the *vitrified process* the abrasive is mixed with feldspar and clay; the mixture being heated to a high temperature in kilns until the clay fuses and bonds the ingredients. The wheels resulting are uniformly of open porous structure, and adapted to all kinds of general work. About 80 per cent of the wheels made are of this type.

In the *silicate process* the abrasive is mixed with silicate of soda; the mixture being subjected to a comparatively low baking temperature, around 500 degrees F., for from 20 to 80 hours. The wheels are smooth cutting and especially adapted for tools requiring a sharp edge.

In the *elastic process* the abrasive is usually bonded with shellac; the mixture being baked at a low temperature, around 300 degrees F., for a few hours. Very thin wheels can be made by this process and they are adapted for cutting off metal, tubing, wire, etc. An extremely high finish can also be obtained by the use of these wheels.

In the *rubber (vulcanite) process* the abrasive is mixed with pure rubber, to which is added sulphur as a vulcanizing agent, and heated under pressure to a temperature sufficient to vulcanize the rubber. Very thin

wheels can be made by this process, and as they have a strong bond they are especially adapted for the cutting of narrow slots and grooves.

BONE BLACK. A material made by heating bones to a high temperature for several hours and grinding the residue. It contains a large amount of calcium phosphate and carbon, has a specific gravity of 2.68, and grinds in 50 per cent of oil. It is used for paints for the protection of iron and steel against corrosion, and to replace carbon-black and lamp black.

BONNET. (1) A cover used to guide and enclose the tail end of a valve spindle. (2) A cap over the end of a pipe (poor usage).

BONTEMPI PROCESS. A method of producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, known as the Bontempi process, consists of heating the articles with hydrogen to a low red heat in a retort, then admitting a small quantity of gasoline, and finally passing steam or fumes of zinc or of some heavy hydrocarbon, such as tar or pitch, over the articles. It is claimed that this method produces a uniform finish of dull black color which will resist corrosion for a long time.

BONUS WAGE SYSTEM. The task or bonus system of wage payment, introduced by H. L. Gantt, is based on the principle of increasing the pay in a certain ratio as the time of completing the job is decreased, the rate of increase in compensation depending upon the percentage of time saved. The system resembles the premium wage system very closely. Each workman always receives his regular hourly rate, a definite standard task is scientifically determined for each worker, and he receives from 50 to 100 per cent extra wages for performing this task within the time limit allowed. If he finishes the task in less than the specified time limit, he is paid his hourly pay for the time actually used for the task, as well as the bonus; he uses the time saved for a new task. The foreman is given a bonus for each man under him who earns a bonus, and receives an additional bonus if all of the men working for him earn a bonus. This stimulates the foreman to aid his men to increase the production. The method insures a definite minimum wage for unskilled labor, and a high reward for skilled and highly efficient men.

BOOSTER. A booster is a generator inserted in series in a circuit to change its voltage. It is generally driven by an electric motor and may be either of alternating or direct current. Alternating-current boosters are mostly used in connection with synchronous-booster converters, and to a certain extent in connection with transmission systems for controlling the voltage of different plants that are operating in parallel on the same system. Direct-current boosters are used in railway stations to raise the potential of the feeders extending to distant points of the system, and also for storage battery charging and regulation. Where there are a number of lighting

feeders connected that run at full load for only a short time each day, it is generally found economical to install boosters rather than to invest in additional feeder copper. Boosters may be non-automatic or automatic in their variation of voltage. The former are used generally for charging batteries, and occasionally for assisting battery discharge, while the latter are used for line-drop compensation and for the purpose of causing instantaneous charge and discharge of a battery on systems supplying energy to loads that fluctuate widely and rapidly in the power demand. Boosters may also be classified as reversible and non-reversible, depending upon whether the current passes through the booster armature in either direction, as for charging or discharging of a battery, or whether it passes in one direction only, continuously through the armature. Boosters may furthermore be self-excited or separately excited, and shunt, series, compound or differential wound.

BOOSTER CONVERTER. A booster converter is a synchronous converter mounted in combination with a series alternating-current generator booster, the field or armature of which is mounted on the same shaft as the converter. The object of the combination is to secure a variable direct-current voltage. The variation in voltage is obtained by changing the field strength of the booster.

BOOSTER ON LOCOMOTIVE. The booster which is applied to some of the modern locomotives is a supplementary engine with small cylinders applicable to the trailing wheels of any locomotive that has trailers. It is used in starting and at slow speeds, and cuts out automatically when the speed of the locomotive reaches about 15 miles an hour. Its operation is similar to the low gear of an automobile. It may be cut in at low speeds in order to get over a heavy grade which might be too steep for the main engine alone.

BOOT. A bin or box built around the lower end of a bucket conveyor or elevator, into which the buckets pass and fill themselves with the material which is placed in this boot.

BORAX. Sodium pyroborate and sodium biborate, a combination of sodium, boron, and oxygen, is known commercially as *borax*. The commercial use of borax is as a flux for soldering and welding. Fused borax dissolves many metallic oxides, forming with them chemical combinations. The use of borax as a flux depends upon the facts that solder adheres only to the surface of an untarnished metal, and that borax placed on the surface of the metal and heated by the soldering iron to the fusing point, removes any superficial film of oxide, and thereby makes it possible for the solder to adhere to the metal surface. Borax is obtainable in two forms: common or prismatic borax, and jewelers' or octahedral borax. The crystals of octahedral borax fuse more easily than those of the prismatic form and

are, therefore, preferable to use as a flux in soldering or welding. Borax is found in large quantities in California, but the main supply is obtained from Italy.

BORING MACHINES. Boring machines may be divided into two general classes, *vertical* and *horizontal*. The standard designs of these machines are not intended exclusively for boring, and very often boring constitutes a small part of the work. For instance, vertical boring machines are very generally used for turning cylindrical, flat, and tapering surfaces, whereas many machines of the horizontal type may be used for drilling, milling, and flange facing. Because of this fact, the names, " vertical boring and turning machines " and " horizontal boring, drilling, and milling machines," are frequently applied to these two classes of machine tools.

Vertical Boring Machine. — The vertical boring and turning machine or " mill " belongs to the lathe family, and is very efficient for work within its range. This type of machine is designed for turning and boring work which, generally speaking, is quite large in diameter in proportion to the width or height. The part to be turned and bored is held to the machine table either by clamps or in chuck jaws attached to the table. When the machine is in operation, the table, which has a vertical spindle, revolves and the turning or boring tools remain stationary, except for the feeding movement. Very often more than one tool is used at a time.

Modern vertical boring mills of medium and large sizes are equipped with two tool-heads, because a great deal of work done on a machine of this type can have two surfaces operated upon simultaneously. On the other hand, small mills have a single head, and ordinarily the tool-slide, instead of having a single tool-block, carries a turret in which different tools can be mounted. These tools are shifted to the working position as they are needed, by indexing the turret the same as on a regular turret lathe. Frequently, all the tools for machining a part can be held in the turret, so that little time is required for changing from one tool to the next. Some large machines equipped with two tool-heads also have a turret on one head instead of the regular tool-block.

Horizontal Boring Machines. — On machines of this class, the bed and cutter-driving spindle are horizontal. These machines are employed principally for boring, drilling, or milling, whereas the vertical design is especially adapted to turning and boring. The horizontal type is also used for turning or facing flanges or similar surfaces when such an operation can be performed to advantage in connection with other machine work on the same part.

The floor type of horizontal boring, drilling, and milling machine, is intended for boring heavy parts such as the cylinders of large engines or pumps,

the bearings of heavy machine beds, and similar work. This machine can also be used for drilling and milling, although it is intended primarily for boring, and the other operations are usually secondary. This design is ordinarily referred to as the "floor type," because the work table is low for accommodating large heavy castings. The spindle which drives the boring-bar, and the spindle feeding mechanism, are carried by a saddle. This saddle is free to move vertically on the face of a column which is mounted on transverse ways extending across the end of the main bed. This construction permits the spindle to move vertically or laterally (by traversing the column) either for adjusting it to the required position or for milling operations. The spindle also has a longitudinal movement for boring. There is usually an outer bearing for supporting the boring-bar.

BORING MACHINES, CAR WHEEL. See Car Wheel Boring Machines.

BORING MACHINES, ORIGIN. The first boring machine was built by John Wilkinson, in 1775. Smeaton had built one in 1769 which had a large rotary head, with inserted cutters, carried on the end of a light, overhanging shaft. The cylinder to be bored was fed forward against the cutter on a rude carriage, running on a track laid in the floor. The cutter head followed the inaccuracies of the bore, doing little more than to smooth out local roughness of the surface. Watt's first steam cylinders were bored on this machine and he complained that one, 18 inches in diameter, was $\frac{3}{8}$ inch out of true. Wilkinson thought of the expedient, which had escaped both Smeaton and Watt, of extending the boring-bar completely through the cylinder and giving it an out-board bearing, at the same time making it much larger and stiffer. With this machine cylinders 57 inches in diameter were bored which were within $\frac{1}{16}$ inch of true. Its importance can hardly be overestimated as it insured the commercial success of Watt's steam engine which, up to that time, had not passed the experimental stage.

BORO-CARBONE. The abrasive known as *boro-carbone* is a product of the electric furnace; it is an oxide of aluminum in crystalline formation, produced by fusing bauxite at a temperature of about 3800 degrees F. The temper of boro-carbone is made to vary according to the kind of work on which it is to be used; its physical formation is such that it presents sharp cutting points when fractured. Boro-carbone is used for grinding all classes of materials of high tensile strength.

BORON. A non-metallic chemical element, the symbol of which is B. The atomic weight of boron is 11.0; the specific gravity, 2.6; and the melting point, 2200 degrees C. (about 4000 degrees F.). It is found in nature in the form of boracic acid and in borax and boracite. It has a strong affinity for oxygen and is, therefore, one of the best deoxidizers known. For this reason

it is employed when casting copper, as it is possible by its use to obtain castings which are sound, free from blow-holes, and having high electrical conductivity. See also Adamantine Boron.

BORON-BRONZE. Boron-bronze is an alloy composed of aluminum and copper, with a small percentage of boron. The addition of boron increases the density of the alloy, and makes it stronger and tougher than ordinary aluminum bronze. It is probable that it is not the percentage of boron actually present in the alloy that exerts so favorable an influence; but more likely the improved qualities are due to the deoxidizing influence of boron in the molten metal.

BORONIZED COPPER. Prior to the use of boron, it was practically impossible to cast copper of mechanical soundness and of high electrical conductivity, on account of the porous metal that was obtained. Boron has a high affinity for oxygen, nitrogen, and oxygen-containing gases which cause the difficulty in copper casting, and since boron has no affinity for copper, it is a natural deoxidizer for copper. The boronizing process delivers a good metal, and the production of a good casting depends upon the same factors as in other metals. The boronized copper shrinks about $\frac{1}{4}$ inch to the foot. Boronized copper castings have a tensile strength of 25,000 pounds per square inch, an elastic limit of 11,500 pounds per square inch, an elongation of 48 per cent, a reduction in area of 75 per cent, and under ordinary foundry conditions an electrical conductivity of 90 (silver = 100).

BORT. Bort is an inferior variety of diamond which is used in the industries for truing soft grinding wheels and for making diamond dies for wire drawing and similar purposes. It is not as hard as the variety of diamond known as the *carbon* or *black diamond*, and is considerably lower in price; but it is not as economical to use as the black diamond for truing hard grinding wheels. While the bort is a semi-transparent stone known as an "imperfect brilliant," and, therefore, uesless as a precious stone, it is very useful as an abrasive agent. It generally occurs in small spherical masses of grayish color. In its commercial usage, the term "bort" is often extended to all small and impure diamonds and crystalline fragments of diamonds which cannot be used as gems. A large proportion of these stones come from South Africa. All classes of diamonds are invariably weighed in carats and in the subdivisions $\frac{1}{2}$, $\frac{1}{4}$, $\frac{1}{8}$, $\frac{1}{16}$, $\frac{1}{32}$ and $\frac{1}{64}$ of a carat. 1 carat (International system) = 3.086 grains = 0.200 gram; 1 ounce troy = 155.5 carats.

BOSH. The lower melting area of a blast furnace, located just above the tuyeres is known as the "bosh." It is generally funnel-shaped, being larger at the upper end than at the lower, the walls making an angle of from 73 to 75 degrees with the horizontal, which form, not only assists the blast to reach

the center of the charge in the furnace, but also aids in supporting the weight of the ore and fuel.

BOWER-BARFF PROCESS. This is a process for protecting iron and steel parts against the corrosive effect of air or moisture by oxidizing the surfaces. In this process, the parts to be treated are heated to a temperature of about 1650 degrees F. in a closed retort, for about forty minutes; then superheated steam is led into the retort for twenty minutes and a coating of a mixture of black and red oxides of iron is formed; producer gas is now substituted for the steam and permitted to act upon the articles for about the same length of time. If the coating formed in this manner is not sufficiently thick, the operations may be repeated several times. Paraffin or some other oil is afterwards applied to the articles. This gives them a heavy black coating, consisting essentially of magnetic oxide of iron, and gives a durable finish. A number of processes have been developed on the basis of the Bower-Barff process which differ in a number of details, but which are based on the same fundamental principle of providing a protective coating of oxide on the iron or steel.

BOW PENCIL AND PEN. The bow pencil is used for drawing small circles as it is a small instrument and easier to manipulate than the ordinary dividers or compass. The bow pen is of similar construction, the only difference being that it is fitted with the blades of a drawing pen instead of a socket for carrying a pencil point.

BOX-JIGS. A great many parts must be drilled on different sides and, frequently, the work is very irregular in shape, so that a jig which is made somewhat in the form of a box, and encloses the work, is very essential, as it enables the guide bushings to be placed on all sides and also makes it comparatively easy to locate and securely clamp the part in the proper position for drilling. As a rule the piece to be drilled can be inserted only after one or more covers or leaves have been swung out of the way.

BOX-TOOLS. The box-tool is a type which is equipped with some form of back-rest opposite the turning tool for supporting the work; it usually encloses or surrounds to some extent the part being turned, for which reason it is known as a *box-tool*. Tools of this type are extensively used on turret lathes and screw machines for turning parts from bar stock. There are many different designs.

BOYLE'S OR MARIOTTE'S LAW. The volume of a gas decreases in the same ratio as the pressure upon it is increased, provided the temperature remains constant. This law is known as Boyle's or Mariotte's law. This law may also be expressed as follows: The product of the pressure times the volume is constant for constant temperatures. Hence, if P = the pressure

on a gas the volume of which is V, and P_1 is the pressure when the same gas occupies a volume V_1, then:

$$P \times V = P_1 \times V_1.$$

BRADLEY PROCESS. A method for producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, in which the articles to be treated are heated in a retort with hydrogen gas to a low red heat, after which a small quantity of gasoline is permitted to enter. The articles are then left in the furnace for an hour, or longer if the coating is not sufficiently heavy, after which they are allowed to cool, and a coating of paraffin or linseed oil applied, which gives them a fine black color and affords additional protection.

BRAKE HORSEPOWER. The brake horsepower is the power of a steam engine or other power generating machine delivered from the flywheel shaft or main driving shaft of the machine. The power expended in overcoming frictional resistance in the engine itself, is not included in the brake horsepower. In order to determine the brake horsepower, a friction brake or dynamometer is applied to the rim of the flywheel, or to the shaft. The *Prony brake* is one of the simplest types of dynamometers to use for this purpose. (See also, Horsepower.)

BRAKES. The purpose of a brake applied to machinery is to absorb energy by creating frictional resistance; the absorbed energy is transformed into heat, and, hence, a properly designed brake must be capable of conveying away the heat as rapidly as possible. The friction in brakes must also be distributed over a sufficiently large area to prevent undue heating of the parts in contact. Brakes with wooden friction blocks on iron drums give satisfactory service if one square inch of friction surface is allowed for each 200 or 250 foot-pounds of energy absorbed. Car brakes running with iron on iron, under conditions very favorable to quick cooling, often absorb as much as from 10,000 to 15,000 foot-pounds of energy per square inch of friction surface. Figures for other types of brakes will lie between these extremes. To facilitate radiation of heat, a ribbed exterior of the casing may be used for block brakes, and also thin ribs or vanes on the brake drum. All radiating surfaces should be left rough and black, because a finished or polished surface confines the heat instead of radiating it into the atmosphere.

Classes of Brakes. — Brakes may be classified, according to their action and construction, in the following three classes:

1. Band brakes, consisting of a flexible band wrapped around the periphery of a drum.

2. Block brakes, consisting of arms carrying blocks arranged to clamp the drum between them.

3. The third class, from the method of application, should be called *axial* brakes, since they are applied in a direction parallel to the shaft; but they are often called *friction* brakes, *load* brakes, *safety* brakes, *automatic* brakes, and *mechanical* brakes. Brakes of this class are usually designed so that the retarding torque is directly proportional to the load sustained, and are largely used on electric and hand cranes for the automatic sustaining of the load should the power fail. The name "automatic brake" is, therefore, used for this class, although this must not be assumed to mean that either of the other two classes of brakes cannot be made to act automatically under certain conditions.

BRAKES, AUTOMATIC TYPE. To safely hoist, hold, and lower a load, hoisting machinery is usually equipped with so-called *safety, automatic*, or *retaining* brakes. These brakes permit a load to be lifted freely by the motor, and lock the brake by the gravity of the action load as soon as the lifting torque of the motor ceases to act in the hoisting direction. The load is retained by the brake in any position, and only when the motor runs in the lowering direction is the acting power of the brake diminished, allowing the load to descend. The speed at which the load drops is regulated and determined by the lowering speed of the motor, while the brake, in the meantime, absorbs by friction the greater part of the potential energy of the dropping load, the energy absorbed by the brake is dissipated in the form of heat.

BRAKES, ELECTRIC. Electric braking is extensively used for the slowing down and stopping of motors driving industrial machinery, especially hoists, cranes, etc. Such brakes are of two general classes: 1. *Solenoid-operated friction brakes*, in which the friction material is directly controlled by electric magnets for obtaining mechanical braking. 2. *Dynamic brakes*, in which the motor acts as a generator, the generating action causing the motor shaft to absorb mechanical energy from the machine to which it is connected and thereby establish a braking action. The latter method is generally supplemented by friction brakes, because the dynamic braking action ceases when the motor comes to rest, and the load may move if not held by a friction brake. See Solenoid Brake; also Dynamic Brake.

BRAKES FOR BENDING. A bending brake is a form of press used in sheet-metal work for forming strips and plates. Brakes are made in both hand-operated and power-operated types. As compared with other presses for forming sheet metals, brakes are wide between the housings and are designed for holding long, narrow forming edges or dies for giving the flat stock whatever shape is required. Brakes are used extensively in the manufacture of various kinds of metal furniture, and for miscellaneous sheet metal bending and forming operations.

BRANCH PIPE. This is a very general term used to signify a pipe, either cast or wrought, that is equipped with one or more branches. Such pipes are used so frequently that they have acquired common names, such as tees, crosses, side or back outlet elbows, manifolds, double-branch elbows, etc. The term *branch pipe* is generally restricted to such as do not conform to usual dimensions.

BRASQUE. Brasque is a carbonaceous lining used for crucibles and furnaces. It may be composed of various carbonaceous materials, formed into a paste; the brasque of large-sized crucibles is often made from anthracite powder, powdered gas carbon, and gas-tar. The brasque of furnaces may be composed of charcoal powder, moistened and rammed in place.

BRASS. Brass is an alloy composed mainly of copper and zinc and sometimes containing small percentages of lead and iron. When zinc is present in small percentages, say about 10 per cent, the color of brass is nearly red, and the alloy is known as "red brass." An alloy containing about 20 per cent of zinc is more yellow, and a number of metals with percentages of zinc around this value resemble gold, and are known as "Dutch" metal, "Mannheim gold," and various other trade names. Ordinary brass for machine construction, piping, etc., contains from 30 to 40 per cent of zinc. A number of the brasses are known by special names, such as admiralty metal, Muntz metal, manganese-bronze (which is not a bronze, but a brass composition, bronze being an alloy in which copper and tin are the basic metals), naval brass, etc.

As used in the industries, brass castings usually contain 65 per cent of copper and 35 per cent of zinc. So-called "low" brasses, which are especially suitable for hot-rolling, contain from 37 to 45 per cent of zinc. The "high" brasses, which are used for cold-rolling and drawing, contain from 30 to 40 per cent of zinc. If lead is present to an amount exceeding 0.1 per cent, the ductility of brass is decreased, and sheet brass intended for drawing should be as free from lead as possible. Brasses that must be machined, however, may contain up to 2 per cent of lead to advantage, as in that case they can be turned at high speed and a better finish obtained. Small percentages of antimony, arsenic, or bismuth in brass make it brittle and cause it to crack when rolled or drawn. In order to make brass resist the corrosion due to salt water, an addition of about 1 per cent of tin has been found advantageous.

BRASS ALLOYS FOR CASTINGS. A free-cutting brass having good casting and finishing properties contains, according to the S.A.E. specification No. 40, the following composition in percentages: Copper, 83.00 to 86.00; tin, 4.50 to 5.50; lead, 4.50 to 5.50; zinc, 4.50 to 5.50; iron, maximum, 0.35; antimony, maximum, 0.25; aluminum, none. This alloy is known as

red brass and good castings made from it should have an ultimate strength of 27,000 pounds per square inch.

Yellow Brass. — A cast brass alloy intended for commercial casting where cheapness and good machining properties are the main consideration has the following composition in percentages (S.A.E. specification No. 41); Copper, 62.00 to 65.00; lead, 2.00 to 4.00; zinc, 31.00 to 36.00; tin, maximum, 1.00; iron, maximum, 0.50; aluminum, none; other impurities, 0.25. Good castings made from this alloy, which is known as yellow brass, should have an ultimate strength of 25,000 pounds per square inch.

White Nickel Brass. — A brass intended for trimmings or other parts requiring a metallic white finish has the following composition in percentages (S.A.E. specification No. 42): Copper, 55.00 to 64.00; nickel, minimum, 18.00; iron, maximum, 0.35; aluminum, none; other impurities, 0.25; zinc, remainder. This white nickel brass should have an ultimate strength of 30,000 pounds per square inch. The higher the nickel content, the more permanent will be the color.

BRASS, CLOCK. See Clock Brass.

BRASS COLORING. Brass and copper may be given many different colors by the use of the proper chemical solutions.

Yellow or Orange Colors. — Polished brass pieces can be given a color from a golden yellow to an orange, by immersing them for the correct length of time in a solution composed of 5 parts of caustic soda to 50 parts of water, by weight, and 10 parts of copper carbonate. When the desired shade is reached, the work must be well washed with water and dried in sawdust. Golden yellow may be produced with the following: Dissolve 100 grains of lead acetate in 1 pint of water and add a solution of sodium hydrate until the precipitate which first forms is redissolved and then add 300 grains of red potassium ferricyanide. With the solution at ordinary temperatures, the work will assume a golden yellow, but heating the solution darkens the color until, at 125 degrees F., it has changed to a brown. A pale copper color can be given brass by heating it over a charcoal fire, with no smoke, until it turns a blackish brown, then immersing in a solution of zinc chloride that is gently boiling, and finally washing thoroughly in water. Dark yellow can be obtained by immersing for five minutes in a saturated solution of common salt containing some free hydrochloric acid which has as much ammonium sulphide added as the solution will dissolve.

Rich Gold Colors. — A rich gold color can be given brass by boiling it in a solution composed of 2 parts of saltpeter; 1 part of common salt; 1 part of alum; 24 parts of water, by weight; and 1 part of hydrochloric acid. Another method is to apply to the work a mixture composed of 3 parts of alum; 6 parts of saltpeter; 3 parts of sulphate of zinc; and 3 parts of common salt. The

work is then heated over a hot plate until it becomes black, and then washed with water, rubbed with vinegar, and again washed and dried. Still another solution is made by dissolving 150 grains of sodium thiosulphate in 300 grains of water and adding 100 grains of an antimony-chloride solution. After boiling for some time, the red-colored precipitate must be filtered off, well washed with water, and added to 4 pints of hot water. Then add a saturated solution of sodium hydrate and heat until the precipitate is dissolved. Immerse the brass articles in the latter solution until they have attained the correct shade. If left in too long they will be given a gray color.

Black Finish on Brass. — There are as many different processes and solutions for blackening brass as there are for browning, and, consequently, only a few can be given. Trioxide of arsenic, white arsenic, or arsenious acid are different names for the chemical that is most commonly used. Its use can be traced back to the fifth century and it is the cheapest chemical for producing black on brass, copper, nickel, German silver, etc. It has a tendency to fade and a much greater tendency if not properly applied, but a coat of lacquer will preserve it a long time. A good black can be produced by immersing work in a solution composed of 2 ounces of white arsenic and 5 ounces of cyanide of potassium in 1 gallon of water. This should be boiled on a gas stove, in an enamel or agate vessel, and used hot. Another cheap solution is composed of 8 ounces of sugar of lead; 8 ounces of hyposulphate of soda; and 1 gallon of water. This must also be used hot and the work afterwards lacquered to prevent fading. When immersed, the brass first turns yellow, then blue, and then black, the latter being a deposit of sulphide of lead.

White Coating. — The white color or coating that is given to such brass articles as pins, hooks and eyes, buttons, etc., can be produced by dipping them in a solution made up as follows: Dissolve 2 ounces of fine grain silver in nitric acid, then add 1 gallon of distilled water and put into a strong solution of sodium chloride. The silver will precipitate in the form of chloride and this must be washed until all traces of acid are removed. Testing the last rinse water with litmus paper will show when the acid has disappeared. Then mix this chloride of silver with an equal amount of potassium bitartrate (cream of tartar) and add enough water to give it the consistency of cream. The work is then immersed in this mixture and stirred around until properly coated, after which it is rinsed in hot water and dried in sawdust.

Gray Colors. — A solution of 1 ounce of arsenic chloride in 1 pint of water will produce a gray color on brass, but if the work is left in too long it will turn black. The brass objects are left in the bath until they have assumed the correct shade, and then are washed in clean warm water, dried in sawdust, and finally in warm air. A dark gray color that can be made lighter by

scratch-brushing can be obtained by immersing the work in the following solution: 2 ounces of white arsenic oxide; 4 ounces of commercially pure (c.p.) hydrocholoric acid; 1 ounce of sulphuric acid; and 24 ounces of water. A steel gray can be produced with the following: 20 ounces of arsenious oxide; 10 ounces of powdered copper sulphate; 2 ounces of ammonium chloride; and 1 gallon of hydrochloric acid. After mixing, this should stand for one day. A 5-per-cent solution of platinum chloride in 95 per cent of water will also produce a dark gray color, if it is painted on and the brass is warmed. Weaker solutions will make the color lighter. Copper can also be colored, but the platinum does not adhere as firmly to the surface as it does on brass. A coating of lacquer is required to make it permanent. By smearing the work with a mixture of 1 part of copper sulphate and 1 part of zinc chloride in 2 parts of water, and drying this mixture on the brass, with heat, a dark brownish color is obtained. If desirous of immersing the work, a weaker solution could be used. The color is changed very little by exposure to light.

Lilac Colors. — The lilac shades can be produced on yellow brass by immersing the work in the following solution when heated to between 160 and 180 degrees F. Thoroughly mix 1 ounce of chloride, or butter, of antimony in 2 quarts of muriatic acid, and then add 1 gallon of water.

Violet Colors. — A beautiful violet color can be produced on polished brass with a mixture of two solutions. First, 4 ounces of sodium hyposulphite is dissolved in 1 quart of water, then 1 ounce of sugar of lead is dissolved in another quart of water, and the two are well stirred together. By heating this mixture to 175 degrees F. and immersing the work the correct length of time, it takes on the violet color. The work first turns a golden yellow and then gradually turns to violet. If left a longer time, the violet will turn to blue and then to green. Thus, this same preparation can be used for all of these colors by correctly limiting the time that the work is immersed.

Green Colors. — When left to the natural action of the atmosphere, or ageing, most of the brasses and bronzes first turn green, especially if near the ocean where the moisture from the saltwater attacks the metal. This green color gradually darkens and then turns brown, and finally black. One solution that will produce the verde antique, or rust green, is composed of 3 ounces of crystallized chloride of iron; 1 pound of ammonium chloride; 8 ounces of verdigris; 10 ounces of common salt; 4 ounces of potassium bitartrate; and 1 gallon of water. If the objects to be colored are large, this can be put on with a brush and several applications may be required to give the desired depth of color. Small work should be immersed, the length of time it is immersed governing the lightness or darkness of the color. After immersion, stippling the surface with a soft round brush, dampened with the

solution, will give it the variegated appearance of the naturally aged brass or bronze. Another solution that will give practically the same results is composed of 2 ounces of ammonium chloride; 2 ounces of common salt; 4 ounces of aqua ammonia; and 1 gallon of water. The work may have to be immersed or painted several times to give it the desired coating, and, after washing and drying, it should be lacquered or waxed.

Brown Colors. — Many different shades of brown can be produced and many different chemicals are used to form solutions or pastes for this purpose. In these mixtures, liver of sulphur, either potassium sulphide or sodium sulphide, is one of the most commonly used chemicals. One-fourth ounce of liver of sulphur in 1 gallon of water will give bronze a brown color, when used cold, but, if heated, it is more effective. The depth of the color is governed by the length of time that the work is immersed. If left in too long, however, it becomes black and if too much liver of sulphur is used the color will also be black. Copper is turned black even with the weak solutions. To set the color, it should afterwards be immersed in water containing a small amount of sulphuric or nitric acid. Brass is not attacked by this solution, but if caustic potash is added it causes the liver of sulphur to color the brass. Then, 2 ounces of liver of sulphur should be added to 1 gallon of water and from 2 to 8 ounces of caustic potash, according to the shade of brown that is desired; the more potash the darker will be the color. A solution composed of $\frac{1}{2}$ ounce of potassium sulphide in 1 gallon of water will produce a gray or greenish color on brass, when cold, but, when heated to 100 degrees F., it produces a light brown; at 120 degrees, a reddish brown; at 140 degrees, a dark brown; and at 180 degrees, a black color.

Bronze Color. — The barbedienne bronze, or brown, color can be produced on cast brass or bronze by immersing in a solution made by dissolving 2 ounces of golden sulphuret of antimony and 8 ounces of caustic soda in 1 gallon of water. The work must be properly cleaned beforehand and afterwards scratch-brushed wet, with a little pumice stone applied when brushing. It must then be well washed and dried in sawdust. A second immersion in a solution of one-half the above strength will have a toning effect, and the work must again be washed and dried. The high light can be made to show relief by rubbing the object with pumice-stone paste on a soft rag. A dead effect can be produced by immersing in a hot sulphuret of antimony solution for ten or fifteen seconds, then rewashing and immersing in hot water for a few seconds, and drying in sawdust. The work should be lacquered to preserve the tones, and waxed when the lacquer has become dry and hard. This brown color can be darkened by a five-seconds immersion in a cold solution of 8 ounces of sulphate of copper in 1 gallon of water. Some other processes use two solutions, the first of which is heated and the second used cold, after which the work is rinsed in boiling water.

Brass Cleaning Before Coloring. — Cleaning brass is of the utmost importance before subjecting it to a chemical coloring process. Several acid dips will remove the films which form on brass, bronze and copper, and leave the bright clean metal with its original smooth surface. Work that will stand heating can be heated to a dull red and then plunged into dilute sulphuric acid, after which it should be soaked in old aqua fortis, and then thoroughly rinsed. It should be soaked long enough to have a uniform metallic appearance, and the bath should be large enough in volume to prevent its heating up from the hot work. The best results are obtained with straw-colored aqua fortis, as the white is too weak, and the red, too strong. In diluting the sulphuric acid, it should always be poured into the water slowly, as heat is generated, and too rapid mixing generates so much heat that the containing vessel is liable to crack and the escaping liquid to cause burns. To pour water into sulphuric acid will cause an explosion that is almost sure to result in serious, if not fatal, burns from the flying liquid.

A good method of removing these films, without heat, is to soak the work in a " pickle " composed of spent aqua fortis until a black scale is formed, and then dip it for a few minutes into a solution composed of 64 parts of water; 64 parts of commercial sulphuric acid; 32 parts of aqua fortis; and 1 part of hydrochloric acid. After that the work should be thoroughly rinsed several times with distilled water. If the strong aqua fortis is used for the pickle in which the work is soaked, it will cause a too rapid corrosion of the copper during the time of the solution of the protoxide. Hence, the spent aqua fortis is more satisfactory on account of its slower action, and it also saves the cost of new.

BRASS COLORS. When brass contains 10 per cent of zinc, the mixture has a true bronze color. With 15 per cent of zinc, the brass has a light orange shade. When the amount of zinc reaches 20 per cent, the color of the mixture is greenish-yellow, and is known as " green brass." With 25 per cent of zinc, the color is practically that of the 20 per cent mixture so that this, too, is a " green brass." Brass with 30 per cent of zinc has the true, yellow brass color. The same is found with 35 per cent of zinc, but at about this point the yellow color begins to disappear, for with 40 per cent of zinc, a reddish-yellow color is found. Brass, therefore, that has a reddish-yellow shade will always contain more than 35 per cent of zinc. The " dead line " seems to be about 38 per cent of zinc, for, at this percentage, the transition from the real yellow to the reddish-yellow begins. When the zinc is increased to 45 per cent, the color of the brass is a rich golden shade and may be called " orange." The mixture containing 50 per cent of zinc has also a golden shade, but richer than the 45 per cent zinc alloy. With 55 per cent

of zinc, the color resembles that of 14-karat gold. When 60 per cent of zinc is reached, the brass has a yellowish-white shade, and as the quantity increases, the color becomes white, and finally gray.

BRASS FORGING. Parts formed to the required shape in dies and made from forgeable brass rod are being used to replace many small castings and screw machine parts. The production of these die-formed pieces may be either by a forging or a hot-pressing process. The term "brass forging" is applied more particularly when dies are used in conjunction with some type of power hammer, such for example as a drop hammer or steam hammer. The heated brass rod is formed in dies by a succession of blows so that the operation is actually one of forging. Hot pressing, according to approved usage of the term, relates more specifically to the use of some form of press in conjunction with suitable dies for forming heated brass slugs by a single press stroke. Thus the metal is forced to fill the die cavity by a powerful squeezing or pressing action, rather than by a succession of blows. Parts produced by hot pressing have also been called die-pressed castings, but the term casting in this connection is somewhat misleading.

Advantages of Brass Forgings. — Brass forgings average 50,000 pounds per square inch tensile strength, as compared with 20,000 to 30,000 pounds per square inch for brass castings. Forgings are made of virgin metal. It is impossible to make a porous forging; while with castings it is difficult to know whether they will leak or not. Forgings are never scrapped or tested for leaks. Forgings contain no sand to dull and wear out tools, and consequently, the life of tools used on forgings is many times longer than that of tools used on sand castings. Forgings are clean, and alike as to strength, shape or size. When chucked, they run true, and for this reason, less allowance for finish is required on a forging. Considerable saving can be shown on screw machine parts, where 30 per cent or more of the stock is turned into chips. If a part has a flange on it, or a hub on each side, it will be economical to forge it. Take the case of piano caster rollers made of bar stock; the bar stock costs $150 for a thousand parts; if forged, the material costs approximately $70 per thousand parts.

Composition of Forging Rod. — The composition of forging rod for brass forgings varies little from a 60–40 mixture. The S.A.E. No. 88 specification of forging rod gives copper $58\frac{1}{2}$ to $61\frac{1}{2}$ per cent; lead $1\frac{1}{2}$ to $2\frac{1}{2}$ per cent; and the remainder, zinc. This material forges and machines freely.

Forging Equipment. — Board drop-hammers for brass forging generally range from 400 to 2000 pounds, and the steam hammers from 300 to 1500 pounds. Gas, oil, or electric furnaces are used to heat the forging rod and slugs. Owing to the small permissible variation in the heat to get the best results, accurate temperature controls should be provided.

Brass Forging Dies. — Dies for board-drop and steam hammers are made of a low-carbon steel. Their average life ranges from 50,000 to 150,000 forgings. This long life is made possible by spreading the operations over several sections of the die. Most dies have, in addition to the finished pair of die cavities, a roller to draw out the stock to a smaller section; a former to form it to the approximate shape of the die cavity; a blocker to prepare the bar to the approximate shape of the finished impression; and a cut-off to cut the forging off the end of bar.

Brass forging dies require approximately the same draft as dies for steel. It is possible, when the sections are not too high, to use a draft of 3 degrees instead of 5 and 7 degrees as is customary on the deeper sections. Due to the softness of brass and copper, it is of the utmost importance to smooth and polish the dies very highly. If a scratch is left, the brass is driven into this crevice, and in a short time a crack will develop.

Accuracy of Brass Forgings. — Forgings will vary by plus or minus 0.005 inch, on an average. If a part is 6 inches long, it will vary in length about 0.010 inch. In commercial practice, forgings may vary by plus or minus 0.0075 inch, unless otherwise specified. See Hot-pressed Brass Parts.

BRASS, HIGH. See High Brass.

BRASS HISTORY IN UNITED STATES. Brass was produced in the American Colonies for the first time at the iron foundry of John Winthrop, Jr., in Lynn, Mass., in 1644. A brass industry, however, did not develop until over a century later. About 1750, John Allen established a brass factory in Waterbury, Conn., the brass being used chiefly in the manufacture of buttons. From this humble start the brass industry of the United States, transplanted almost bodily from England, has grown to be the greatest brass industry in the world.

BRASS, HOT-PRESSED. See Hot-pressed Brass Parts.

BRASS LATHE. The "brass lathe" is so called because it is designed especially for operating on brass parts of various kinds. A typical machine is equipped with a screw-chasing attachment similar to the type found on Fox or monitor lathes, and the tailstock is mounted on a cross-slide. There is no tool carriage, but a T-rest for supporting hand-manipulated tools. When a turret is added to a lathe of this general design, it may be known either as a *turret lathe*, *Fox lathe*, or *monitor lathe*. The *square-arbor lathe* is also used for brass work and derives its name from the fact that the spindle or arbor of the tailstock is square instead of being cylindrical. The spindle is made square in order that it will better withstand torsional strains incident to tapping or drilling. This type of lathe has been widely used by brass workers, and has been regarded as a very effective type where work

is done that does not require a multiplicity of tools and a monitor or turret lathe.

BRASS, LOW. See Low Brass.

BRASS ROD, FREE-CUTTING. See Free-cutting Stock.

BRASS ROD, HARD AND SOFT. The terms "hard" and "soft" as applied to brass rod have different meanings to the manufacturer and to the user. To the user, the term "hard," applied to brass rod, means that it is difficult to cut; the term "soft" means that it is easy to cut. To the manufacturer, the term "hard" means high tensile strength, stiffness, and high Brinell, scleroscope, and Rockwell hardness numbers, and does not necessarily mean that the rod is difficult to cut. The manufacturer uses the words "free-cutting" and "not free-cutting" to describe the cutting qualities.

In steel and iron, metal that has high strength and Brinell hardness is generally not free-cutting, and metal that has low strength and Brinell hardness is free-cutting. In brass, the same relation does not necessarily hold. In brass, the most important factor in determining free-cutting properties is the lead content. This should be maintained at about 3 per cent; if it runs much above this, trouble will be experienced in manufacture, and in the rod itself, due to lack of strength; if it runs below 3 per cent, the maximum free-cutting properties will not be attained. The difference in lead content explains why brass rod made abroad does not cut so readily as similar stock made in this country. It also explains why tubing as a rule is "harder" (in the meaning of the user) than brass rod. If the lead content of brass tubing is higher than about 1 per cent, difficulty is met with in manufacture. The hardness (strength, stiffness, etc.) of brass is controlled largely by the amount that it is drawn, either from the extruded size or after the last annealing. This has comparatively little to do with the free-cutting properties of the rod. The rod should be drawn stiff enough so that the cutting tools will not push it out of shape. The required results are obtained by accurate control of the composition and processing of the rod.

BRASS SHEETS. Commercial brass sheets which conform to the S.A.E. specification No. 70 are composed of: Copper 64.50 to 67.50 per cent; lead, maximum, 0.30 per cent; iron, maximum, 0.05 per cent; other impurities, maximum, 0.10 per cent; zinc, remainder. Sheet brass, the temper of which is designated as "quarter hard," has a reduction of 1 B. & S. gage number; "half hard," a reduction of 2 gage numbers; "hard," a reduction of 4 gage numbers; "extra hard," a reduction of 6 gage numbers; and "spring," a reduction of 8 gage numbers. The annealed sheets are designated as "light anneal"; "drawing anneal"; "soft drawing anneal."

BRASS TUBING. Seamless brass pipe is made in the same sizes as steel and iron tubing and pipe; the brass in the tubing consists of from 60 to 70 per cent of copper, from 30 to 40 per cent of zinc, and should not contain more than 0.5 per cent of lead.

BRASS WIRE. Brass wire is generally composed of from 63 to 67 per cent of copper and from 33 to 37 per cent of zinc. The tensile strength ranges from 40,000 to 80,000 pounds per square inch, increasing with the percentage of zinc in the alloy.

BRAZED-SEAM PROCESS. A method for making brass tubing, in which a brass plate is bent into tubular form and welded or brazed at the joint. The brazed tube is afterwards drawn to size through dies.

BRAZILIAN CORUNDUM. A natural abrasive obtained from Brazil, containing about 76 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. Brazilian corundum is not considered of as high a grade as *Canadian corundum.*

BRAZING. Brazing is a method of joining metal parts together by means of an alloy known as *spelter solder*, or simply as *spelter*, which is melted into the joint and unites with the metals. Brazing is practically the same as *hard soldering*, but, according to the commonly accepted meaning of the two terms, there is the following distinction: Brazing means the joining of metals by a film of brass (a copper-zinc alloy); hard soldering is the term ordinarily applied when silver solder is used, the latter being an alloy of silver, copper, and zinc. For brazing, a red heat is necessary, and a flux (borax or boracic acid) is used to protect the metal from oxidation, and to dissolve the oxides formed. The part to be brazed is heated either by means of a blow-torch, gas forge, or a coke or charcoal fire. For very small work, an alcohol lamp or gas jet is often used, the heat being intensified by using a blowpipe. As a considerable amount of heat is required to melt the spelter solder, brazed work will withstand more heat without breaking or weakening than parts which are united by soldering. The chief advantage of a brazed joint, however, lies in its superior strength.

The ordinary process of brazing consists, briefly, in assembling the parts to be brazed, applying a suitable flux and the spelter solder (or hard solder) to the joint, and heating the joint until the spelter solder melts and unites with the parts to be joined. The method of holding the parts in place while brazing depends upon their shape. If practicable, they should be secured in such a way that the work can be turned over during the process of brazing without disturbing the relation of the parts, thus affording a better chance to apply the flux and spelter. Brazing is an operation requiring considerable experience. The secret of successful brazing is the thorough cleaning of

the joint that is to be brazed. " Well cleaned is half brazed " is a true saying.

The principal difference between *dip brazing* and ordinary brazing is that the work is immersed into the spelter solder while the latter is in a liquid state. The spelter is contained either in a cast-iron tank or graphite crucible, the size of which depends upon the size of the parts to be brazed. *Muffle brazing* differs from ordinary brazing in that the parts to be united are enclosed in a tube or muffle. This insures uniform heating, clean smooth surfaces, and is especially adapted to brazing alloys, the melting temperatures of which are rather close to that of the spelter.

BRAZING, HYDROGEN PROCESS. By the use of atmospheres of protective gas in electric furnaces, steel parts used in the manufacture of complicated assemblies can be united by a strong alloy weld. This method, known as hydrogen brazing, involves the welding together of the parts to be joined by means of a copper flux. As the result of development work by the General Electric Co., hydrogen brazing may now be applied successfully to many operations with resulting simplification of method and reduction of costs, owing to improvements in the equipment used.

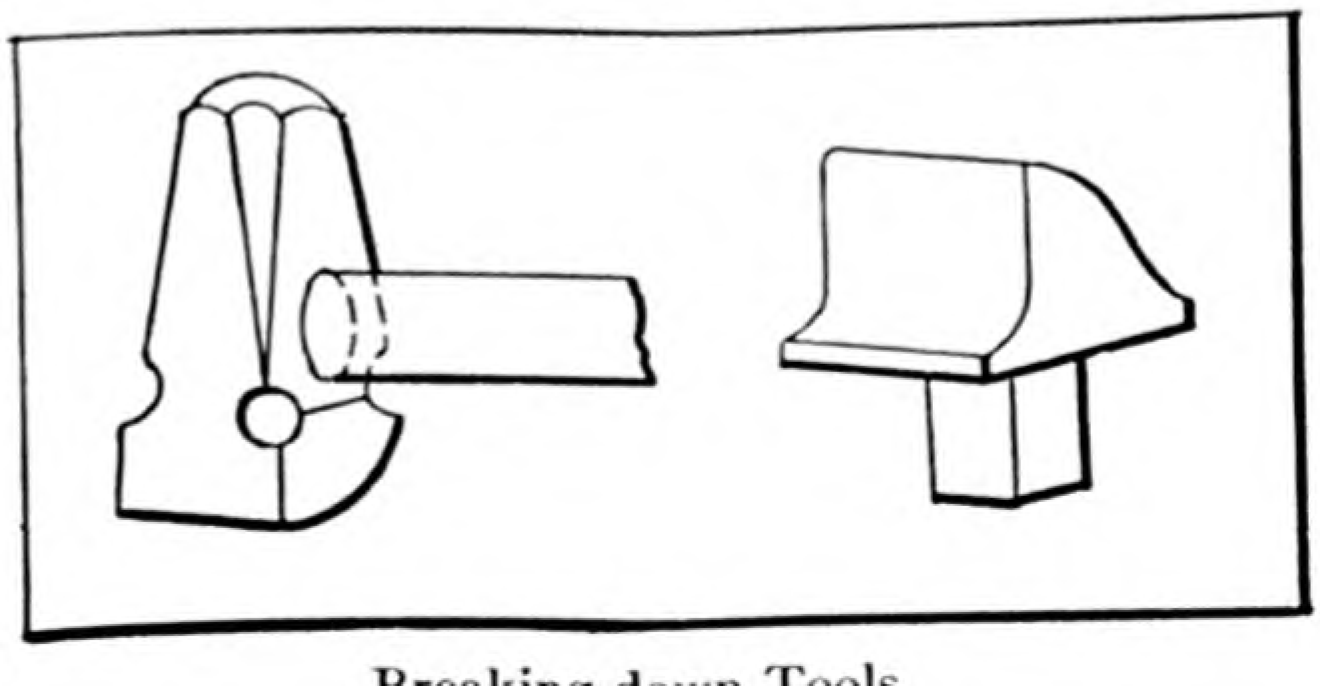
Electric furnaces of small size, utilizing protective atmospheres, have been used for brazing by this method for some years. An early and important use was the manufacture of steel shafts for golf clubs. The theory of the process involves the reducing action of a hydrogenated atmosphere, which thoroughly cleans the surfaces to be joined, and the capillary attraction of the fluid copper, causes it to diffuse quite generally over the surface and to be drawn into the minutest joints between the parts. The protective atmosphere is also essential during the cooling period, and for this reason the usual type of furnace cannot be used. A typical hydrogen brazing furnace consists of three " stages." Each stage is in the form of a platform. Covers which may be raised and lowered are provided for two of the stages. The work to be brazed is first assembled on one stage, copper wire or chips being placed adjacent to the joints to be united. The assembly is then placed in the heating chamber at a suitable temperature, and the next stage loaded. When the first assembly has been suitably heated over a predetermined period of time, it is withdrawn from the heating chamber and placed in a cooling chamber, the second assembly automatically moving into the heating chamber. Thus the heating, cooling and assembly may take place at the same time.

Bright Annealing Application. — Another application on which the protective gas envelope is used to advantage is bright annealing steel in sheet or fabricated form, for nickel, monel and certain other non-ferrous metals, to save the cost of annealing pots, handling, pickling, etc. In such work, a

furnace of the continuous type is used, designed for larger output. The work is loaded on suitable trays arranged to be pushed through the furnace on a roller track. An elevator raises the trays into the furnace at the entrance end and a similar elevator is used to remove them from the discharge end. An hydraulic cylinder is used to push the work through the furnace. Heating takes place in only one portion of the furnace, the remainder being provided with a water jacket for cooling; thus the work is both heated and cooled in the protective gas atmosphere.

BRAZING, SPELTER SOLDER. The spelters employed in brazing are composed of alloys of copper and zinc. The melting point of copper-zinc alloys may be regulated by varying the percentage of zinc, the melting temperature decreasing as the proportion of zinc increases. The fusing point of spelters should be as close as possible to that of the article to be brazed, as a more tenacious joint is thereby secured. An easily fusible spelter may be made from two parts of zinc to one part of copper, but the joint will be weaker than when a spelter more difficult to fuse is employed. A readily fusible spelter may be made with 44 per cent of copper, 50 per cent of zinc, 4 per cent of tin, and 2 per cent of lead. Alloys containing much lead, however, should be avoided, since lead does not transfuse with brass and thus decreases the strength of the joint. A hard spelter for the richer alloys of copper and zinc may be produced from 53 parts of copper and 47 parts of zinc. Brass spelter is sometimes used for copper and iron articles, as these metals have a much higher melting point than brass, thus allowing the use of a richer copper alloy. In these cases tin is often added as one of the ingredients, but it should be sparingly used as it increases the brittleness of the spelter. Ordinarily the spelter solder used for brazing is obtained from manufacturers of such supplies. In making brazing spelters, it is important that the metals used should be commercially pure, as impurities interfere with the color, malleability, and strength.

BREAK CLEARANCE. The term "break clearance" is sometimes used to indicate the clearance between a blanking punch and its die. The purpose of this clearance is to reduce both the pressure required for the blanking operation and the strain on the punch; thus, the stock subjected to shearing action between the edges of the punch and die, breaks easier, which accounts for the name "break clearance."


Breaking-down Tools

BREAKING-DOWN TOOLS. Breaking-down tools are used

in blacksmith shops for "breaking-down" square shoulders upon work, part of which is to be drawn down to smaller dimensions. They are straight on one side of the face, the other being made circular (see illustration). Breaking-down tools should be made with the edge rounded, which will prevent leaving a cold shut where the shank joins the body of a forging.

BREEZE. Pulverized coke fuel used mainly for covering the bottoms of soaking pits and crucible furnaces for protecting the brickwork.

BRICKWORK, FURNACE. See Furnace Brickwork.

BRIDGE REAMERS. Taper reamers used in bridge and structural iron work are generally known as *bridge* reamers or *taper bridge* reamers; they are employed for reaming the rivet holes in structural work, and are made either with a Morse taper or straight squared shank. The fluted part is tapered for part of its length and the remaining part is straight. The taper is 1 inch per foot for the $\frac{1}{2}$ inch size, and increases to $1\frac{1}{2}$ inch per foot for the $1\frac{1}{4}$ inch size.

BRIDGE SOCKETS. A type of wire rope socket used especially for suspension bridge work and large aerial cable-ways is known as a *bridge* socket. Two types of bridge sockets are made, the open and closed, the former consisting of a casting with a tapered conical hole into which the cable or wire rope is inserted, spread and held up, the interstices being filled with babbitt, lead, or zinc. Two eye-bolts are provided with nuts and pins. The closed type is similar to the open type except that it consists of a U-bolt instead of the two eye-bolts.

BRIGGS PIPE THREAD. The Briggs pipe thread is used for pipe joints and is the standard for this purpose in the United States. It derives its name from Robert Briggs, and is also known as the American Standard and American Briggs Standard.

BRIGHT DIP FOR POLISHING. Where there are a great many brass parts to be finished, especially in shops where repair parts are refinished, a bright dip is commonly used. A piece that is badly tarnished, and that would ordinarily require a polishing or buffing operation, can be put into good condition quickly by the use of a bright dip. The parts are first thoroughly washed in a potash cleaning solution, in the same way that they are before plating. If several small pieces are to be bright dipped, it is advisable to wire them together, while in handling large pieces, a brass hook answers the purpose. After cleaning, the piece is first dipped into cold water and then into the *acid* bath. The acid solution is made of equal parts of commercial nitric and sulphuric acids; and a cupful of common salt is added to the contents of a 20-gallon crock. The piece must not be left too long in the acid less than a second is often long enough — and one dipping is usu-

ally sufficient; but the experienced workman may find it advisable to dip a piece more than once, depending upon the nature of the metal.

Upon being taken from the acid, the piece is again dipped in cold water, after which it is dipped in a *cyanide bath* for an interval of a second or two, the purpose being to remove all signs of tarnish from the surface of the metal. In making up the cyanide solution, $1\frac{1}{2}$ pound of cyanide crystals is dissolved in a 20-gallon crock of water. In some cases, it may be found advisable to dip the work in the cyanide solution two or three times; no harm will be done if the work is left in it for several minutes. After being removed from the cyanide bath, the work is again dipped into cold water and then into hot water, to heat the metal so that it will dry quickly. If the drying takes too long, the work is likely to have a streaky appearance. For small work, it may be advisable to use a hot sawdust bath, which is simply a box filled with sawdust and having steam coils for heating to the required temperature.

BRINELL HARDNESS TESTING. Instruments which employ the Brinell principle of testing hardness, measure the hardness of the work in terms of its tensile qualities. A steel ball is forced into the work under a known pressure, and the diameter of the impression is measured by a microscope; by the use of tables the spherical area of the impression then is converted into Brinell numbers according to the following formula:

$$\frac{\text{Known pressure}}{\text{Area of impression}} = \text{hardness number}$$

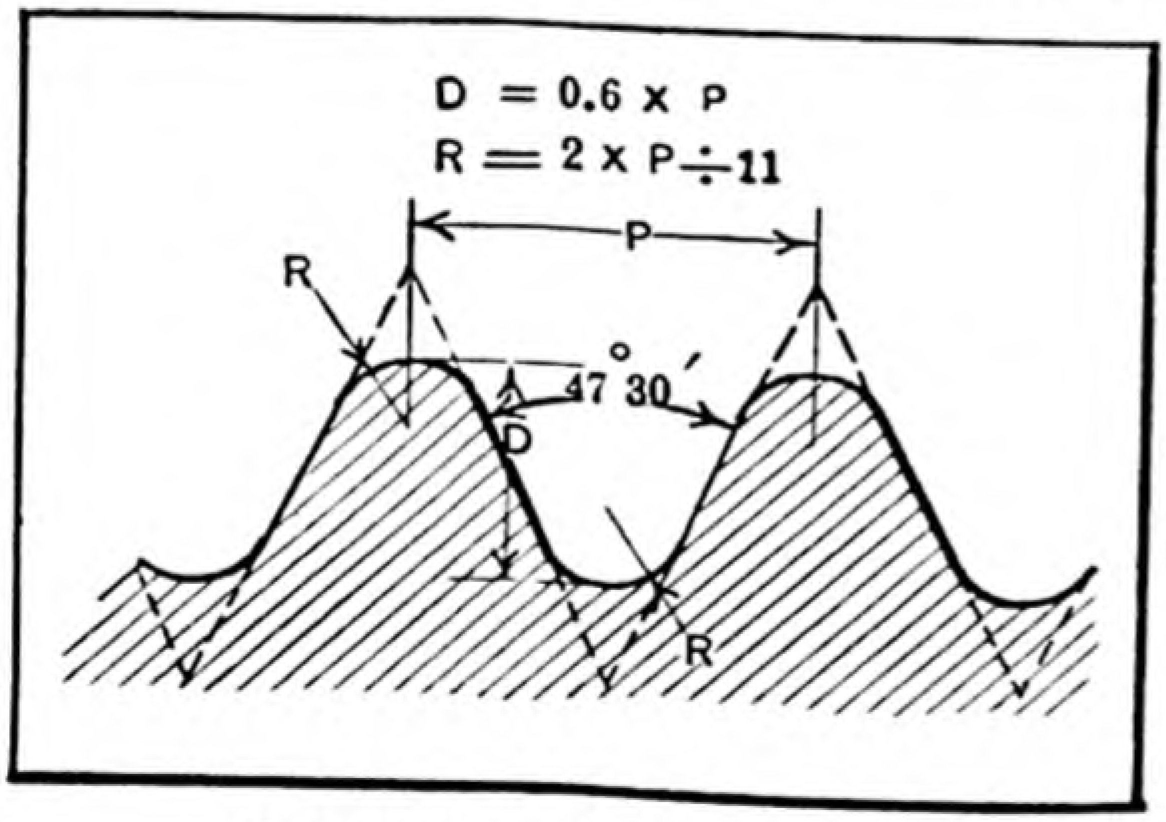
This method of testing is most satisfactory. The mass, chucking, and set-up does not affect the readings, but the strain imparted by the weight through the ball weakens comparatively frail work in the vicinity of the impression, and mars the surface in some instances. The surface of the metal tested must be polished sufficiently to reflect back to the eye-piece of the microscope light enough so that the rim of the depression can be seen. The surface must be a true plane for best results, or else the impression will not be round but may be elliptical, having two diameters; thus two diameter readings will be necessary, and final results must be based on the average. For this reason round bar stock must be ground off to a considerable depth. The Brinell instrument is limited in its use to the size of the work; small gun components, etc., cannot be tested in this manner. The error in test and reading is given by authorities as ± 0.05 millimeter in diameter of the impression. This means that at a reading of 600 Brinell, for instance, the variation might be 27 numbers either way.

BRIQUETTING METAL CHIPS. The *Ronay process* for briquetting metal chips, without the use of a binding material, was developed by Arpad Ronay. This process subjects every part of the material to heavy hydrau-

lic pressure, so great that a comparatively solid briquette is formed. In order to produce the greatest possible solidity, it is necessary that the air be thoroughly expelled. The air cannot be expelled if the pressure is exerted in the mold from one direction only. It is necessary to exert direct pressure on the briquettes from at least two sides. Briquettes produced by this process, in which all air is expelled, melt in the furnace with little or no more waste than pigs of new metal. The pressure employed approximates 35,000 pounds per square inch.

BRITANNIA METAL. Britannia metal is an alloy containing tin, antimony, and copper as the chief ingredients. It is made in various compositions, many of which also contain zinc, lead, or bismuth. Britannia metal is used extensively in the manufacture of silver-plated ware. While the color of britannia metal is white, it is almost invariably silver-plated. Britannia metal is made in much the same manner as babbitt metals, by first melting the copper in a crucible with a small percentage of tin or antimony. This mixture is afterwards added to the balance of the tin and antimony alloy. Several compositions of britannia metal, determined by analysis, are as follows: Tin, 90 per cent; antimony, 6 per cent; copper, 2 per cent; bismuth, 2 per cent. Tin, 86 per cent; antimony, 10 per cent; copper, 1 per cent; zinc, 3 per cent. Tin, 80 per cent; antimony, 10 per cent; copper, 3 per cent; zinc, 1 per cent; lead, 6 per cent. Tin, 70.5 per cent; antimony, 25.5 per cent; copper, 4 per cent.

BRITISH ASSOCIATION THREAD. This form of thread is similar to the Whitworth thread in that the root and crest are rounded (see illustration). The angle, however, is only 47 degrees 30 minutes and the radius of the root and crest are proportionately larger. This thread is used in Great Britain and, to some extent, in other European countries for very small screws. Its use in the United States is practically confined to the manufacture of tools for export. This thread system was originated in Switzerland as a standard for watch and clock screws, and it is sometimes referred to as the "Swiss small screw thread standard."



British Association Thread

BRITISH STANDARD FINE SCREW THREAD (B.S.F.). The form of this thread is the same as that of the Whitworth thread, but the number of threads per inch for a given diameter is greater than in the Whitworth standard system.

BRITISH THERMAL UNIT. The unit quantity of heat adopted in the English-speaking countries is the British thermal unit (B.T.U.). A British thermal unit is the quantity of heat that is required to raise the temperature of one pound of pure water one degree F. Strictly speaking, the measure or unit of heat is the quantity required to raise the temperature of one pound of water one degree, at its point of greatest density. Although this occurs at about 39 degrees F., it is customary, in ordinary computations, to disregard the temperature and to define a heat unit or British thermal unit simply as the quantity of heat required to raise the temperature of one pound of water one degree. The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the *mechanical equivalent of heat* and equals 778 foot-pounds. One foot-pound = 0.001285 heat unit. The various power equivalents of a British thermal unit are as follows: 1 B.T.U. = 1052 watt-seconds = 778 foot-pounds = 0.252 kilogram calorie (French or metric thermal unit) = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pound of water evaporated at 212 degrees F.

BRITISH THERMAL UNIT VALUES. See Heat Density; Heat Equivalent of Work; Fuel Oil Heating Value; Gasoline.

BRITISH WIRE GAGES. The standard British wire gage, usually known simply as Standard wire gage (frequently abbreviated S.W.G.), but also known as the New British Standard (abbreviated N.B.S.), and also frequently known as the British Legal Standard or Imperial wire gage, is the legal standard for wires in Great Britain, by order in Council, August 23, 1883. The Birmingham or Stub's iron wire gage is also used for some purposes, especially for designating the sizes of brass wire, but only to a limited extent. On the whole, it may be considered obsolete; while it is sometimes referred to as Stub's gage or Stub's iron wire gage, it should not be confused with the Stub's steel wire gage, which is still a commonly used gage for steel wire, drill rod, and drill diameters. The Birmingham wire gage is usually abbreviated B.W.G.

BROACH. A broach is a metal-cutting tool having a series of teeth formed around it so that it is adapted to cut when drawn or pushed through a rough-cored or drilled hole in a longitudinal direction. The teeth on the broach increase slightly in size from one end of the tool to the other, so that, when the broach is forced through a hole, the teeth successively cut the hole to the required form. Broaches may be *pull broaches* or *push broaches*, depending upon whether they are to be pulled or pushed through the hole in the work.

Broach Pitch. — Pitch, in its relation to broaches, is defined as the distance between successive teeth. The pitch determines in part the length of

the broach, and so should be made as fine as possible if maximum production is to be attained, because with the modern adjustable-stroke broaching machine, production varies inversely with the length of the cutting tool.

There are limitations, however, to the fineness of the pitch. In the first place, the pitch must be coarse enough to allow ample chip room between the teeth. The depth of cut per tooth also governs the pitch somewhat. An ordinary broach has only sufficient room between its teeth to carry off the chips from one cutting stroke. There must always be two, and there should preferably be three, cutting teeth in the work at a time; otherwise, the part being broached will drop down between the teeth. This difficulty may be eliminated, and often is when several thin pieces are stacked for broaching at one stroke, by affixing a support to the faceplate of the machine, which will hold the work rigidly in place. While the number of teeth in the work should never be less than two, there should not be an excessive number cutting at one time. If this is the case, the stress on the tool will be beyond the breakage point or the driving nut of the machine will become heated.

Practice has proved that if the number of broach teeth in the work at a time is somewhere between three and six, all of the considerations relative to pitch are satisfied and the tool will function properly. The broach designer need merely divide the length of the work that the prospective tool is to cut, by a constant in order to determine the pitch, which is calculated to the nearest $\frac{1}{16}$ inch. This constant is the number of teeth that should be in the work at one time, and is as follows for several types of broaches: Square broaches, from 3 to 5; spline broaches, from 3 to 6; keyway cutter-bars, from 3 to 6; round broaches, 3; and special-shaped broaches, 3.

Few commercial broaches are made with the pitch over $1\frac{1}{4}$ inches, and by far the greater part of the work for which broaches are used is less than 10 inches in length. When the work is over 4 inches long, the designer adopts a plan which permits him to keep the pitch $1\frac{1}{4}$ inches or under in the majority of cases. Teeth 1 inch or more apart are rugged enough to permit the back to be machined away considerably without weakening them to the breaking point; hence the bottoms of spaces between broach teeth of 1-inch pitch and over are usually flatted to give the necessary additional chip room for long work.

BROACH, BURNISHING. See Burnishing Broach.

BROACHING. The broaching process consists in machining holes in castings or forgings by drawing or pushing through the rough cored or drilled hole, one or more broaches to cut the hole to the required form. Broaching is especially adapted to the finishing of square, rectangular, or irregular-shaped holes and is also an efficient method of finishing round holes on certain classes of work. It is also applicable to a wide variety of

miscellaneous work, such as the cutting of single or multiple keyways in hubs, forming splines, cutting teeth in small internal gears and ratches, etc. The advantages of the broaching process are speed, interchangeability of work, adaptability to irregular forms, employment of comparatively unskilled labor, and adaptability to a great variety of work.

There are two general methods of broaching: One is by pushing comparatively short broaches through the work, usually by means of a hand press, a hydraulically operated press, or an ordinary punch press. With the other method, a special broaching machine is used, and the broach, which is usually much longer than a " push broach," is pulled through the work by means of a screw forming part of the machine. The cutting speed for broaches ordinarily varies from about 3 feet per minute, for heavy broaching operations, to about 4 feet, for lighter work, whereas the return speed usually varies from 8 or 10 feet to 18 feet per minute.

BROACHING MACHINES. The function of a broaching machine is to draw the broach through the work at the proper speed. As broaching is done by a series of cutting teeth which gradually increase in size, in order to produce the required shape progressively, considerable power is required for pulling the broach through the work, especially when cutting hard, tough material. For this reason, a broaching machine must be so designed that it can exert considerable power. The broach is secured to a draw-head which is operated either by a screw or hydraulically. The stroke of the machine is automatically controlled by adjustable tappets.

A duplex or double type of broaching machine is used in some plants in order to increase production on certain classes of work. The distinctive feature of this machine is that there are two operating screws, so that two broaches can be used at the same time. The design of the machine is such that one head is returning while the other is on the cutting stroke.

BROACHING MACHINE, VERTICAL DUPLEX TYPE. This special type of broaching machine is designed for finishing machine parts having flat or irregular surfaces, and it is intended for quantity production. One or more surfaces are roughed and finished in one operation. Two uprights extend above the machine bed and support slides which hold the broaches and operate alternately up and down on the ways of the uprights. These slides counterbalance each other, one moving up as the other moves down. They operate continually at a speed depending upon the nature of the work, and in front of each slide there is a " tip-up " work-holding fixture. When a slide is at the bottom of its stroke, the fixture is in a horizontal position and the piece to be machined is placed in it while the slide moves up. When the piece is in place, a lever is tripped, and — provided the lever is operated before the slide reaches the top of the stroke — the fixture is automatically

tipped to an upright position. Then the slide moves down and the piece is broached, the fixture being automatically thrown back into the horizontal position for unloading and reloading. If the trip-lever is not operated before the slide reaches the top of the stroke, the fixture will not be tipped up until the next cycle. The lower teeth on the broach rough the work, and the upper teeth take a light finishing cut. The broaches are solidly supported directly behind the cutting edges.

BROMINE. Bromine is one of the non-metallic chemical elements allied in its chemical relations to chlorine and iodine. Its chemical symbol is Br, and its atomic weight, 79.9. At ordinary temperatures it is a dark reddish liquid which is opaque except when in thin layers. It has a specific gravity of 3.2 at 32 degrees F. It changes from the solid to the liquid state at −7 degrees C. (+19 degrees F.); its boiling point is at 59 degrees C. (138 degrees F.); its latent heat of fusion equals 16.18 calories; latent heat of vaporization, 45.6 calories; and specific heat, 0.107. Bromine is slightly soluble in water. When dropped on the skin, it produces corrosive sores. The chief uses of bromine are in analytical chemistry, where it is of some importance on account of its oxidizing action. The salts of bromine are widely used in photography, especially bromide of silver. Bromine does not occur free in nature, but is manufactured mainly from magnesium-bromide.

BRONZE. Bronze is an alloy composed mainly of copper and tin in variable proportions, and sometimes containing small percentages of zinc, antimony, lead, aluminum, phosphorus, or manganese. *Phosphor-bronze* contains from 85 to 95 per cent of copper, from 5 to 10 per cent of tin, with a maximum of 4 per cent of zinc, 0.2 per cent of lead, 0.06 per cent of iron, and 0.15 per cent of phosphorus. *Manganese-bronze* contains from 57 to 60 per cent of copper, from 0.5 to 0.75 per cent of tin, from 37 to 40 per cent of zinc, 1 per cent of iron, and 0.30 per cent of manganese (and sometimes 0.5 per cent of aluminum). The name "manganese-bronze" is a misnomer, because the alloy consists mainly of copper and zinc and is, hence, a brass rather than a bronze. *Gun bronze* consists of from 87 to 89 per cent of copper, from 9 to 11 per cent of tin, from 1 to 3 per cent of zinc, and a maximum of 0.06 per cent of iron and 0.2 per cent of lead. A number of other bronzes known as *journal bronze*, *valve bronze*, etc., are made with varying compositions. *Bell metal* is a bronze containing 80 per cent of copper and 20 per cent of tin, and the metal used for Chinese gongs is a bronze of similar composition. The name "bronze" is also used for alloys with copper and various other metals, even when these alloys are nearly or entirely lacking in tin; thus, for example, aluminum bronze is mainly an alloy of copper and aluminum. A bronze known as *deoxidized bronze* resembles phosphor-bronze in its composition, in that it contains zinc and iron in small per-

centages. The composition is generally as follows: Copper, 82.5 per cent; tin, 12.1 per cent; zinc, 3.2 per cent; lead, 2.1 per cent; and iron, 0.1 per cent. See also Manganese-bronze; Non-gran Bronze; Phosphor-bronze; Silicon Bronze; Tobin Bronze.

BRONZE, EARLY USE. Copper was first produced from ores about 5000 years before the Christian era. About this time bronze became known, not by melting copper and tin together, but rather because the ores available contained tin, nickel and small amounts of other metals, and produced alloys harder and stronger than copper. The Bible mentions Tubal Cain as a worker in brass and refers to the alloy in several places. There is reason to believe that not brass but bronze is intended. In the first century Dioscorides makes the earliest unmistakable reference to brass (an alloy of copper and zinc); nevertheless, it was known to the Far East long before. Owing to confusion in names, no approximation of a definite time when brass came into use is possible.

BRONZE GEAR CASTINGS. See Gear Castings, Bronze.

BRONZING. Bronzing is a process by means of which a bronze-colored surface is produced on objects made from other metals or from wood, plaster, or other materials. A bronze-like color can be produced by exposing iron or steel parts to the vapors of heated *aqua regia*, then dipping them in melted vaseline, and finally heating them until the vaseline begins to decompose, when they are wiped off with a soft cloth. Bronze-like colors may also be produced by slightly heating the work, covering the surface with a paste of antimony chloride, also known as "bronzing salt," and letting the object stand until the desired color is obtained. The paste of bronzing salt may be made more active by adding a small quantity of nitric acid. Bronze colors can also generally be produced on metals by the action of dilute nitric acid and sal-ammoniac. The so-called "antique bronze" appearance is produced by painting over the bright metal with a solution of sal-ammoniac, cream of tartar, silver nitrate, and common salt. Plaster and wood are bronzed by first coating the articles with a sizing and then covering them with a bronze powder produced by powdering brass or bronze.

BROWN & SHARPE TAPER. A standard taper used for taper shanks on tools such as end mills and reamers, the taper being $\frac{1}{2}$ inch per foot for all sizes except for taper No. 10, where the taper is 0.5161 inch per foot. Brown & Sharpe taper sockets are used for many arbors, collets, and machine tool spindles, especially milling machines and grinding machines. In many cases there are a number of different lengths of sockets corresponding to the same number of taper; all these tapers, however, are of the same diameter at the small end.

BROWN & SHARPE WIRE GAGE. The Brown & Sharpe wire gage, also known as the American wire gage, is the gage universally recognized in the United States as the standard gage for copper wires and wires of metals other than steel. The diameters of the wires of successive numbers increase according to a geometrical ratio. The diameter of each succeeding number can be found by multiplying the diameter of the preceding number by 1.123, this being the ratio of the geometrical progression. The basic size is No. 36 wire, which is 0.005 inch in diameter.

BRUSHES, MOTOR. The brushes of a direct-current motor are those parts of the mechanism which, being held in some form of flexible holder, rest upon the commutator surface at proper points about its periphery and distribute current to or from the commutator segments. The brushes also perform the function of uniting the commutator segments to which are connected adjacent coils to be commutated, thus making a proper continuous circuit around the armature. They are made of a conducting material, generally of graphite or carbon, although metal or metal compound brushes are used extensively in some special applications. The brush material, being relatively soft, forms a good surface of contact with the commutator, thus reducing the resistance to the passage of current between the commutator and the external source of power to a minimum. The brush rigging or holders and mountings must be such as to afford minimum inertia to the brush, since its function is to aid the brush in following the more or less uneven surface of the commutator when the latter revolves.

BRUSH-SHIFTING MOTOR. A brush-shifting motor is an electric motor consisting of a stator with a three-phase distributed winding and a rotor similar to that of a regular direct-current motor, but with a larger number of brushes which can be shifted through worm-gearing by means of a handwheel. This type of motor is used in order to obtain speed control, as it may be started, accelerated, stopped, and reversed by shifting the brushes. Compared with an ordinary induction motor with rheostatic control, much higher efficiency and a better power factor are obtained with a brush shifting motor.

BRUSH SWITCHES. A brush switch resembles very closely an open-arc circuit-breaker and, in fact, is generally a circuit-breaker with the automatic feature omitted, and because of this, it is sometimes erroneously spoken of as a "non-automatic" circuit-breaker. Brush switches are especially used where large currents are to be carried, and are seldom made in capacities under 2000 or 3000 amperes. Brush switches, like circuit-breakers, may be arranged to be operated by hand, by a solenoid, a motor, or a compressed-air mechanism. They are not generally used to open under load, but are so constructed that this can be done if required. They are

usually made in single-pole, single-throw units, although it is possible to make them single-pole, double-throw; in the smaller capacities, they may be multi-pole, but, when so arranged, are always single-throw. Under ordinary circumstances, plain lever switches are to be preferred to the brush switch. *Remote control switches* are small capacity brush switches of 300 amperes or less.

BUCKET CONVEYORS. Bucket conveyors consist of a series of equally spaced buckets attached either to a belt or a chain. Grain conveyors are always encased in wooden and steel casings, and the casings are nearly always vertical. The usual support for the buckets in this case is belting — either leather, cotton, or rubber. For coal, coke, and other heavy materials, the buckets are fastened to chain links, either single or double strand, depending upon the capacity for which the conveyor is designed; and, in this case, the conveyor casing is usually carried in a slanting position. Conveyors in a vertical position are only suitable for specifically light material and can be run at a circumferential velocity of from 250 to 350 feet per minute. Conveyors for heavy material must be wholly or partially inclined to give a clean delivery without scattering, and they should run at a speed of from 50 to 160 feet per minute. Bucket conveyors should always be driven from the top so that the upward side of the conveyor (the side containing the load) can be tight, while the empty side will run slack.

BUCKET ELEVATOR. A device practically the same as a *bucket conveyor*, except that it is used in a vertical or nearly vertical direction. It consists chiefly of a belt or detachable link chain to which buckets containing the material to be lifted are attached, the belt or chain passing over pulleys or sprockets at the top and bottom. The top pulley or sprocket is power-driven.

BUCKING. An electrical term used to designate the condition where the potential from one source is opposing that from another source.

BUCKWHEAT COAL. Small coal of such size that the pieces will not pass a screen of $\frac{3}{8}$-inch mesh, but pass a screen of $\frac{1}{2}$-inch mesh. Buckwheat coal is often used for power plant purposes.

BUFFING. Buffing is the process of obtaining a very fine surface, having a " grainless " finish, on metal objects, by means of soft wheels of felt to which a fine polishing material is applied, or by wheels formed of layers of cotton cloth. The term " buffing " is often used interchangeably with " polishing." The operation is performed with any wheel to the face of which the abrasive is loosely applied, rather than glued as in polishing. Buffing is not so harsh an operation as polishing. The abrasives which are glued to a polishing wheel are intended to grind away roughness that the

grinding wheel or other cutting tool leaves — unevennesses that are often discernible only with the aid of a microscope. Buffing, on the other hand, employs such soft cutting materials as tripoli, lime, crocus or rouge prepared in cake form with tallow and other greases as a body, this being applied to the cloth buff by hand from time to time so that the face of the buff is given a coating of this composition. Some metals, like German silver and white metal, are buffed before plating. Pocket-knife blades are polished with emery and then highly finished (colored) by what is known as " crocus polishing," in which a wheel, similar to a leather-faced wood polishing wheel is used for buffing. Steel parts to be plated are usually prepared for plating by polishing, buffing being employed to give a luster to the plated surface. The term *sand buffing* relates to the finishing of German silver, white metal, and similar materials. As compared with the ordinary buffing operation that is used only to produce a very high finish, sand buffing actually removes considerable metal as in rough polishing or flexible grinding. For sand buffing, rotten-stone and pumice are loosely applied.

BUFFING MACHINES. See Polishing or Buffing Machines.

BUFFING WHEELS. The Metal Finishers' Equipment Association defines buffing wheels as wheels manufactured from disks (either whole or pieced) of bleached or unbleached cotton or woolen cloth, and used as the agent for carrying abrasive powders, such as tripoli, crocus, rouge, lime, etc., which are mixed with waxes or greases as a bond. There are two main classes of buffs known as the " pieced-sewed " buffs, which are made from various weaves and weights of cloths, and the " full disk " buffs which are made from the best sheeting and shirting. Bleached cloth is harder and stiffer than unbleached cloth, and is used for the faster cutting buffs. Coarsely woven unbleached cloth is recommended for highly colored work on soft metals, while the finer woven unbleached cloths are better adapted for the harder metals. A stiff buff when working at the usual speed is not suitable for " cutting down " soft metal or for use on light plated ware, but is used on the harder metals and for heavy nickel-plated articles.

BUFFINGTON PROCESS. A method for producing a protective oxide coating on iron and steel. The articles to be coated are immersed cold in a molten bath of manganese dioxide and potassium nitrate; the articles are next removed and hung over the iron pot in which the bath is contained, so as to be exposed to the fumes from the mixture. They are then placed in boiling water. Colors varying from blue to bronze may be produced in this manner.

BUILT-UP SECTION. A structural beam, column, or strut, composed of two or more single structural shapes.

BULGING METHOD OF FORMING SHELLS. In the manufacture of many sheet-metal parts, operations, such as bending, forming, and expanding can be performed economically by the hydraulic bulging method. The work is placed in a die, which is usually split, and water under a pressure varying from 600 to 1200 pounds per square inch is admitted from either a hydraulic accumulator or a force pump. A force pump is generally sufficient for the purpose, and gives a ready means of varying the fluid pressure; the initial cost is also low. In the case of hollow work, the water under pressure is admitted directly into the work itself, so that in this respect it differs from the older method of hydraulic bulging, in which the quantity of water is measured, put into the receptacle to be bulged, and the operation performed under a power press.

With the improved method, a power press is not required, and the construction of the dies is so simple that their first cost is much less than when the combined mechanical and hydraulic operation is employed. Furthermore, the method of operation does not depend for its success upon the watchfulness of the operator in measuring the fluid. It is merely necessary to insert the work in the lower half of the dies, clamp the top half in position, admit the water under pressure from a suitable water cock and drain the water off after the piece has been formed. Another advantage of the process is the rapidity with which the water pressure forms the article to the desired shape, the time required being not more than one-sixth that taken by the other method. An important point to be considered is the water pressure, which must be governed by the thickness of the metal and its physical characteristics. A safe pressure to use at first is about 700 pounds per square inch for annealed brass 0.020 inch thick, increasing this to approximately 1200 pounds per square inch for a thickness of 0.060 inch.

BULL BLOCK. In wire drawing, a bull block is a machine in which wire or rod is drawn in order to reduce it into wire of the required diameter.

BULL CENTER REAMER. A conical reamer used for reaming the ends of large holes — usually cored — so that they will fit on a lathe center. The cutting part of the reamer is generally in the shape of a frustum of a cone. It is also known as a pipe center reamer.

BULLDOZER. The bulldozer is a machine especially adapted for bending operations, and is closely allied to the forging machine; in fact, many operations can only be done successfully on forging machines when the bulldozer is used for performing a preliminary operation. This type of machine contains a cross-head which carries one member of the forming dies; the other member of the dies is held against a die seat which is formed integral with the main base of the machine. This base or bed is horizontal and the cross-head slides upon horizontal ways or ways which are slightly inclined. The stock

to be formed is placed between the dies, and, as the cross-head moves forward, the stock, which may or may not be heated, is bent to conform to the shape of the dies, the work as a rule being completed in one movement of the cross-head. While the machine is quite simple in construction and operation, many interesting types of forming tools and dies are employed on different classes of bulldozer work. Many of the tools or dies are made of cast-iron, in order to reduce the cost, and those parts of the dies which are subjected to wear are faced with hardened steel plates which may readily be replaced, if necessary. Whenever hot punching or cutting is done, high-speed self-hardening steel should be used for the working members of the tool.

BULL WHEEL. The gear in a planer drive which meshes with the rack beneath the platen and through which the motion of the platen is obtained.

BUNSEN BURNER. The device known as the "Bunsen burner" was invented in 1855 by Prof. R. W. von Bunsen of Heidelberg, and provides a simple means for burning ordinary coal gas with an extremely hot smokeless flame. The object of the burner is to procure a flame capable of producing great heat, but which will not smoke any vessel or article heated by it. The force of gas, escaping through a small aperture, draws the air through holes in a sleeve surrounding the jet. The air and gas mix together, consuming the carbon produced by the decomposing gases before it becomes incandescent, and producing the flame desired.

BUNSEN CELL. The Bunsen cell is one of the well-known primary electrical batteries which is, in general, similar in construction to the Daniell cell in that a zinc plate is placed in dilute sulphuric acid, but in the Bunsen battery the copper cylinder is replaced by one of carbon, and the copper sulphate solution, by strong nitric acid. The Bunsen cell gives a high electromotive force, varying from 1.9 to 1.95 volt. It has also low internal resistances, and can, therefore, be used for producing fairly large currents. The battery gives off fumes of nitric peroxide and must, therefore, be placed in the open air or under an exhaust flue. The battery must be taken apart when not in use, because the mixing of the liquids through the walls of the porous jar containing the dilute sulphuric acid would render it useless after a short time. The porous jar should be placed in water after having been used, so that the zinc sulphate solution may be dissolved out of the pores of the jar. Otherwise, when the jar dries, the zinc sulphate solution will crystallize in the pores and cause the jar to crumble to pieces.

BUOYANCY. Any body that is immersed in water, or in any other liquid, is subjected to an upward force equal to the weight of the mass of the liquid that is displaced by the body. This is true whether the body sinks or

floats. The weight of a floating body is equal to the weight of the volume of the liquid that it displaces. The upward pressure on the body is known as *buoyancy*. It may be assumed to be exerted at the center of gravity of the displaced liquid, which point is known as the *center of buoyancy*. In a floating body, at rest on the water, the line joining the center of gravity of the body and the center of buoyancy is always vertical, and is known as the *axis of equilibrium*. If an external force causes this axis of equilibrium to occupy an inclined position, then, if a vertical line be drawn upwards from the new center of buoyancy to this axis, the point where it intersects the axis is called the *metacenter*. If the metacenter is above the center of gravity, the body is in stable equilibrium, and tends to return to the original position when the external force is removed.

Weight of Submerged Body. — A body submerged in water or other fluid will lose in weight an amount equal to the weight of the fluid displaced by the body. This is known as the *principle of Archimedes*. To illustrate, suppose the upper surface of a 10-inch cube is 20 inches below the surface of the water. The total downward pressure on the upper side of this cube will equal the area of the side multiplied by the product of the depth, in inches, to which the surface is submerged and the weight of 1 cubic inch of water. Thus, the downward pressure equals $10 \times 10 \times 20 \times 0.03617$ (weight of 1 cubic inch of water) $= 72.34$ pounds. The upward pressure on the under side equals $10 \times 10 \times 30 \times 0.03617 = 108.51$ pounds. The weight of the water displaced by the body equals $10 \times 10 \times 10 \times 0.03617 = 36.17$ pounds; and $108.51 - 72.34 = 36.17$ pounds. This excess of upward pressure explains why it is comparatively easy to lift a submerged stone or other body.

BUREAU OF STANDARDS. One of the important functions of the U. S. Bureau of Standards is to compare with its own standard of measurements, the measuring instruments used by states, cities, scientific laboratories, educational institutions, and commercial corporations. The Bureau also gives advice concerning these standards and their use, and many questions of disagreement either between corporations, or between the public and a corporation, involving the use of standards, are referred to the Bureau for advice or adjustment. The Bureau also certifies the accuracy of standards of measurement, such as gages, and in addition publishes a great deal of information relating to measurements and standards of all kinds, in the form of small booklets, each dealing with one definite subject. Numerous tests and investigations are carried on in this connection. The materials of construction are also dealt with by the Bureau. The activities of the Bureau of Standards are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output of the industries.

BURNERS FOR FUEL-GAS. Small furnaces equipped with burners for using illuminating gas, are manufactured in a large variety of styles and sizes. Air at a pressure of about one pound per square inch is used. The general requirements of the common types of burners, for either illuminating or cold producer gas, are a mixer where the air and gas are combined, and one or more nozzles or burners outside of which the mixture burns. The velocity of the issuing mixture must be greater than the velocity of flame propagation or ignition in the mixture used. If the velocity is too low, the flame will burn back into the nozzle and overheat it.

BURNERS FOR FUEL OIL. The common method of burning fuel oil in metallurgical furnaces is that in which the oil is sprayed or atomized by steam or compressed air, either the oil or the atomizing agent, and often both, being under a relatively high pressure. Fuel oil may be burned satisfactorily for some purposes by feeding it to the center of a pile of coarse granular refractory material as by the " flameless combustion " methods. It may also be burned in a " pan burner " when the flow and distribution of air and the combustion chamber conditions are suitable. Probably the most common type of burner may be called the concentric jet burner, in which the oil nozzle is in the center of the nozzle through which the atomizing agent flows. In some of these burners, the outside nozzle is made adjustable along the common axis, the end of the oil nozzle being made large enough so that the area of the air or steam outlet can be varied according to the volume passing through. In this way, better atomization can be secured when the burner is running below its normal capacity.

" BURNING ON " OR " CASTING ON." The expressions " burning on " or " casting on " relate to a method of repairing or of filling in a broken part of a casting. Thus if a part has been broken from a casting it may be reunited or a new part formed, by pouring molten metal over the surface that is to be repaired until it becomes plastic or begins to melt. Two pieces that have broken apart can be united by chipping away the edges to expose the surfaces that are to be burned. They are then placed together and a core fitted around them leaving the entire top side exposed. An overflow channel is made in the core to carry the surplus metal away. The burning is accomplished by pouring a constant stream of metal onto the break until the surfaces become plastic, when the pouring is stopped, leaving the opening between the break filled with metal. There is usually quite a lot of metal to chip away after burning, but many castings have been saved by this operation, especially prior to the introduction of modern welding processes.

BURNISHING. The burnishing of metals is a method of securing smooth finished surfaces by compressing the outer layer of the metal, either by the

application of highly polished tools, or by the use of steel balls which, by rolling contact, produce smooth surfaces.

Burnishing of Spun or Drawn Shapes. — After sheet metal is spun, or drawn in presses, the smooth, even surface which it has when it comes from the mills is changed to a rough, uneven surface having high and low spots which are hardly noticeable to the naked eye, but very easily distinguished under the magnifying glass. The working operations distend or elongate the molecules, and the annealing operation restores them to their original shape. Some shells are annealed several times before the burnishing operation is reached, besides being pickled after each annealing to remove the scale; this leaves the surface of the metal in a matted condition, as well as soft and without temper.

A spun shell can be gone over with a planisher, and hardened, but the scale and dirt is crowded into the grain of the metal and the only way to obtain a smooth surface is to buff or cut it down until this pitted face is removed, thus wasting about 10 per cent of the metal. The spinner can do this in another way, that is by skimming or shaving the uneven surface, but even more metal is wasted than by buffing, and the shell is also weakened by gouging the high places. This same shell could be left without polish, and the chuck transferred to the burnishing lathe, which runs at much greater speed than one used for spinning. After the shell is dipped bright to remove all spinning dirt and scale, it can then be polished to an even surface, the uneven face of the metal being amalgamated or smoothed down to a bright surface of the proper temper; it is then colored with a cloth buff to obtain a perfect finish. The gage or thickness remains the same, as there is no dirt or scale to buff out. It is necessary to have a metal chuck in burnishing, and where the shell has been spun on such a chuck, the latter can be used for both operations. Some work can be lacquered without coloring on the buff wheel, the only operation after burnishing being to wash in hot water and dry at once in hot sawdust.

Burnishing Tools. — Burnishing tools are made extremely hard and no temper is drawn. These tools have to be re-polished when they become coated with metal, the interval between polishings depending upon the texture of the metal worked and its temper, a shell that has been annealed several times coating the tool more than one that has not. The end of a burnisher may be polished quickly. A board of soft wood is used, or a strip of leather fastened to a board and to the bench, in a position convenient to the operator. Grooves are worn into the leather or board, and flour of emery and oil, or flint flour and water, is used to clean the tools, a few passes of a tool being all that is necessary to polish it.

Cleaning Work for Burnishing. — The bright dip which is used to clean work before burnishing is composed of oil of vitriol (sulphuric acid), 2 parts;

aqua fortis (nitric acid), 1 part. This solution should be kept in a crock set in a tank of running water, and mixed 7 or 8 hours before using, as the acids when combined heat up. It is best to mix the acids the day before using. In dipping brass, copper, and German silver, the parts are strung on a stiff brass or copper wire whenever possible. If there are no holes in the metal that can be used for stringing, they can be put in a metal or crock basket, but they cannot be handled to good advantage as it is very difficult to thoroughly wash and dip them. The work should be washed in boiling potash, and then dipped in cold water to clean the potash off and cool the metal. After cooling in the water, the parts are dipped for a few seconds in the acids, and are kept constantly in motion, so that the surfaces will be all exposed equally; they are then shaken thoroughly above the acid and immediately washed in two separate cold-water baths, then in hot soapy water, and finally in hot water, after which they are dried at once in hot sawdust. This operation will leave a bright, clean surface free from acid.

Lubricants for Burnishing. — Common yellow soap, dissolved to thick paste, may be used as a lubricant when burnishing brass. The shells and the finger pads are dipped in clear water, and the tool is dipped in the soap paste before burnishing each shell. A lubricant for copper is made by dissolving about one ounce of ivory or castile soap in a gallon of water. The shells and pads are dipped in this solution, no lubricant being used on the tool. Yellow soap should not be used on copper, as the action of the rosin on copper is different from that on brass, the metal being so glazed or greased that the tool works badly. For copper plate on steel, such as copperized steel oilers, etc., about one-half ounce of oil of vitriol to four gallons of water should be used. The burnishing tool should be dipped in a mixture of mutton tallow that has been melted with 5 per cent of beeswax, and the work and the finger pads should be dipped in the acid mixture. The tool is lubricated in the tallow mixture before burnishing each shell.

For German silver, the shell should be dipped in clear water, the finger pads in sour beer, and the tool in yellow soap paste. For white metal or Britannia, use ivory or castile soap in the paste form for the tool, and sour beer or ox gall in water (4 ounces to the gallon) for the finger pads. Wash the work in hot alkali water (a spoonful of cream of tartar, saleratus or soda to a pail of water), and dry in hot sawdust. For burnishing work which is to be lacquered, without coloring on the cloth buff, use thin glue for a lubricant, and also on the finger pads. When the part is burnished, put it in saleratus water to keep it from tarnishing; then wash in hot water and dry in hot sawdust.

BURNISHING BROACH. This is a broach having teeth or projections which are rounded on the top instead of being provided with a cutting edge,

as in the ordinary type of broach. The teeth are highly polished, the tool being used for broaching bearings and for operations on other classes of work where the metal is relatively soft. The tool compresess the metal thus making the surface hard and smooth. The amount of metal that can be displaced by a smooth-toothed burnishing broach is about the same as that removed by reaming. Such broaches are primarily intended for use on babbitt, white metal, and brass, but may also be satisfactorily used for producing a glazed surface on cast iron. This type of broach is also used when it is only required to accurately size a hole.

BURNISHING BY BALL PROCESS. Barrel burnishing is done to finish, polish, or brighten metal parts without cutting away the stock, steel balls acting as individual burnishing tools. Tilting barrels are sometimes used for ball burnishing when the work is small, but the horizontal type is universally recommended. The hardened and polished steel balls roll over the work while under pressure, and rub against the parts evenly. The pressure is caused by the weight of the balls and the work in the barrel. Some manufacturers claim that a horizontal barrel, large in diameter and comparatively small in width, is the best type to use, because a certain quantity of balls will not spread over so large a space, and will therefore create a greater pressure on the work. In this type of barrel, about two pecks of steel balls should be used for one peck of work, and to this should be added a sufficient quantity of soapy water to rise one inch above the contents of the barrel. Soapy water serves as a lubricant. About six ounces of pure soap or soap chips without much alkali should be put in each pail of water. Another manufacturer claims that a barrel of small diameter, and comparatively long, completely filled with work, balls, and soapy water, is more efficient than the type just mentioned. It is said that the work then passes constantly and evenly through the mass of balls without bumping and falling against each other.

Polygon-shaped barrels prevent the work from bunching together and sliding instead of tumbling inside the barrel. Balls from $\frac{1}{16}$ to $\frac{1}{4}$ inch in diameter are generally used, the size depending on the work and dimension of the cavity or corners in the pieces; the balls should be small enough to enter all cavities, and to insure this, a round steel slug with a fin-like edge is sometimes used. Articles to be barrel-burnished must be cleaned and must be free from oil or dirt. Double and triple burnishing barrels permit of burnishing more than one class of work at a time. Burnishing barrels permit the finishing of hundreds and thousands of small pieces at one time quickly and inexpensively.

BURNISHING DIES. When an exceptionally good finish or polish is required, blanks which have been trimmed in a shaving die are pushed

through what is known as a *burnishing die*. Such a die has an opening which tapers slightly inward toward the bottom, and it is finished very smooth, so that, when the blank is forced through by the punch, the metal around the edges is compressed and polished. Naturally, the degree of finish on the blanks will depend largely upon the finish of the burnishing surface of the die.

BURNISHING GEAR TEETH. Gears are sometimes finished by a burnishing operation. One commercial type of gear burnishing machine has three arbors and three master gears — one driving and two driven. The operator places the gear in position between the master gears and pushes a lever down, which brings the gear into engagement with the driving burnishing gear. Throwing the control switch, starts the machine in the forward direction, and after it has made a predetermined number of revolutions (adjustable by dogs), the spindle reverses and makes the same number of revolutions in the opposite direction; then it stops automatically. The pressure with which the gear engages the burnishing gear is adjusted by raising the whole carriage by means of a crank. The carriage can be locked in place or left free. In the latter case, constant pressure is maintained on the gears by a counterweight.

BURNISHING LATHES. A burnishing lathe is smaller than a spinning lathe, and it has only one speed although the speeds of different lathes are varied to suit the work. The countershaft is fastened to the floor under the lathe; this is necessary on account of the great speed; besides a downward pull of the driving belt causes less vibration than the upward pull of a belt from an overhead countershaft. The burnishing is done by pushing the tool over the work, beginning at the front end and pushing always against the chuck or form over which the work is held. The toolpost is used as a fulcrum and the tool, which is pressed against the work, as a lever. The tool is given a slight rotary motion, and only the thin edge or end is used. While the pressure against the work is not great, the area in contact with the metal is so small, and the speed of the lathe so high, being from 3200 to 5000 revolutions per minute, that the tool leaves a bright surface. The skill of the operator lies in passing the tool over the metal so as to leave a continuous bright surface without any trace of the tool marks; to do this the tool must be fed with regularity and without overlapping or leaving any dull places.

BURNISHING ROLLER. The roller type of burnishing tool is sometimes used in machine shops, especially railway repair shops, for rolling the cylindrical surface of a journal, crankpin bearing surface, etc., in order to obtain a smooth dense finish. The burnishing tool consists of a hardened roller or disk which is supported by a shank held in the lathe toolpost. The

leading edge or side of this disk is rounded and the burnishing is done by feeding the roller over the surface the same as in turning. The roller may be mounted on a plain bearing, but tools of improved design are equipped with roller bearings.

BURRING MACHINES. Special machines and tools are sometimes used to remove the burr left on machine parts by cutting tools. One design of machine is intended especially for slightly countersinking the rear ends of holes in parts produced in automatic screw machines to remove the burr left by the cutting-off tool. This machine is semi-automatic. The parts are fed by hand into a chute and are pressed against a gage-block by a reciprocating link attached to toggle levers which exert sufficient pressure to prevent the part from rotating during the burring operation. When the link withdraws to transfer another part from the bottom of the chute, the burred blank drops out of the fixture. The burring is performed by a tool held in the spindle of an automatic sensitive drill head.

Gear Burring Machine. — A machine of this type is designed for removing the burrs left on the ends of gear teeth after the hobbing or cutting operation. One type of machine is provided with a burnishing tool and a shearing tool. The burnisher resembles a hob without gashes, and it meshes with the gear, thus forcing the burrs to project from the ends of the teeth at an angle so that the stationary shearing tool can readily cut them off.

BUS-BARS. The common connections to which several generators deliver their current, and from which several feeders draw their supply, are termed *bus-bars* or *busses*. These busses may be solid copper wire, tubing, or flat bars, depending upon the amount of current to be carried. Flat bars are usually 2, 3, 5, or 10 inches wide, and $\frac{1}{8}$ or $\frac{1}{4}$ inch thick. These are, whenever possible, mounted on edge, with spaces between the laminations equal to the thickness of the bars, to allow free circulation of air to assist in cooling the bars. For small capacities, round solid wire is used, and for high voltages and long spaces, tubing is often used. Investigations have shown that the cross-section necessary to carry a given current varies with the nature of the current; for instance, bus-bars heat more when carrying 60-cycle alternating current than with lower frequency or direct current.

BUSHEL. See Dry Measure.

BUSHING. A lining or sleeve that is inserted in a hole usually to provide convenient means of restoring a worn hole to its original size by inserting a new bushing. A "bushing" is also a pipe fitting which is used for the purpose of connecting a pipe with a fitting of larger size; it is a hollow plug with internal and external threads to suit the different diameters.

BUSHING BRONZE. See under Gear Castings, Bronze.

BUSHING CHAIN. What is known as the built-up block or bushing chain resembles somewhat a roller chain, but differs from the latter in that the bushings between the side links are not provided with rollers. The operation of this rollerless chain is similar to that of the solid block chain. It will fit sprockets intended for roller chains, provided the pitch and diameter of the rollers are of corresponding size. These chains are recommended when considerable power is to be transmitted and the speed is low. The rivet wearing surface is large in proportion to the pitch of the chain.

BUSHINGS, GRINDING WHEEL. See Grinding Wheel Bushings.

BUSSES. A term sometimes applied to bus-bars. See Bus-bars.

BUTT JOINT. A joint made either by welding or riveting, in which the two ends of the plates joined are abutted squarely against each other without over-lapping. In the case of the riveted butt joint, the two ends of the plate are usually rivetted to two plate strips that straddle the joint above and below.

BUTTON LOCATING METHOD. Among the different methods employed for accurately locating work such as jigs, etc., especially on the faceplate of a lathe, one of the most commonly used is known as the "button method." This method is so named because cylindrical bushings or buttons are attached to the work in positions corresponding to the holes to be bored, after which they are used in locating the work. These buttons, which are ordinarily about $\frac{1}{2}$ or $\frac{5}{8}$ inch in diameter, are ground and lapped to the same size, and the ends are finished perfectly square. After the buttons are all set in correct relation with each other and have been tightened, the work is mounted on the faceplate of the lathe, and one of the buttons is set true with the axis of the lathe by the use of a test indicator. This button is next removed; the hole is then drilled nearly to the required size, after which it is bored to the finish diameter. In a similar manner, the other buttons are set in the central position one after another, and the holes bored. It is evident that if each button is correctly located and set perfectly true in the lathe, the various holes will be located at the required center-to-center dimensions within very close limits.

BUTT-WELDED PIPE. Skelp used in making butt-welded pipe comes from the rolling department of the steel mills with a specified length, width, and gage, according to the size of pipe for which it is ordered. The edges are slightly beveled with the face of the skelp, so that the surface of the plate which is to become the inside of the pipe is not quite as wide as that which forms the outside; thus when the edges are brought together they meet squarely. The skelp for all butt-welded pipe is heated uniformly to the welding temperature. The strips of steel, when properly heated, are seized

by their ends with tongs and drawn from the furnaces through bell-shaped dies or "bells," as they are called. The inside of these bells is so curved that the plate is gradually formed in the shape of a tube, the edges being forced squarely together and welded. For some sizes, the pipe is drawn through two bells consecutively at one heat, one bell being just behind the other, the second one being of a slightly smaller diameter than the first.

The efficiency of a butt weld depends largely upon the relationship of the thickness to the diameter of the tube. The thickness should be sufficient to enable considerable pressure to be put upon the two butting edges without fear of buckling or overlapping of the material, but it must not be so thick that the stress required in putting sufficient pressure on the weld involves a pull on the tube which, after it leaves the ring, may reduce or break it. With the standard thicknesses of gas, water, and steam pipe, of the sizes to which this process is usually applied ($\frac{1}{8}$ to $1\frac{1}{2}$ inch for standard gas, water, and steam thicknesses of these sizes), these conditions are fulfilled, but with heavier pipes it is necessary to effect the welding in several successive passes through graded rings. The production of pipes by butt welding is usually restricted to sizes varying from about $\frac{1}{4}$ to 2 inches, although pipes as large as 3 inches or even 4 inches have been made in this way. The usual commercial limit, however, is about 2 or $2\frac{1}{2}$ inches. When a very great resistance to inside pressure is required, or when it is essential to use comparatively thin metal, the butt-welding method is impracticable.

BY-PASS VALVES. When valves are of five or six inches in diameter and upward, and are used for live steam or water under considerable pressure, the type of valve having a by-pass is often used. The object of the by-pass is to equalize the pressure on each side of the valve, so that it can be opened more easily.

CABBLE. In the making of wrought iron, to cabble is to break up the iron bars into pieces, preparatory to reheating and re-rolling. A "cabbler" is a man engaged in this work.

CABINET FILE. A cabinet file is one that is flat on one side and rounded on the other, but which is wider and thinner than a regular half-round file. It is double-cut, with coarse, bastard teeth. This type is made for cabinet makers and wood-workers generally.

CABLE. A cable, generally, is a hemp, Manila, or wire rope twisted together from a number of different strands. In electrical engineering, a cable is defined by the Bureau of Standards as (1) a conductor of electric current, composed of a group of wires, usually twisted or braided together; or it may consist of (2) a combination of conductors insulated from one another, generally known as a "multiple-conductor" cable. The component conductors of the second kind of cable may be either solid or stranded, and this cable may or may not have a common insulating covering. The first kind of cable is a single conductor, while the second is a group of several conductors. The term "cable" is applied by some manufacturers to a solid wire heavily insulated and lead covered; this usage arises from the manner of the insulation, but such a conductor is not included under the Bureau of Standard's definition of "cable." Cable is a general term, but, in practice, it is usually applied only to the larger sizes. A small cable is called a "stranded wire" or a "cord." Cables may be bare or insulated, and the latter may be armored with lead, or with steel wires or bands.

Duplex Cable. — Two insulated single-conductor cables twisted together. They may or may not have a common insulating covering.

Twin Cable. — Two insulated single-conductor cables laid parallel, having a common covering.

Triplex Cable. — Three insulated single-conductor cables twisted together. They may or may not have a common insulating covering.

CABLE-LAID ROPE. A cable-laid wire rope is a compound rope consisting of several other ropes laid together into one. A cable, for instance, may be made up of six ropes twisted together, each of the six ropes, in turn, consisting of six strands, each of which strands is composed of seven wires. Such a cable-laid rope would be described as a 6 by 6 by 7 rope or cable.

CADILLAC SCREW THREAD. The Cadillac screw thread is so named because it was adopted by the Cadillac Motor Car Co. The thread angle is 60 degrees and the top is flat like the U. S. standard thread, but the bottom or root of the thread is a sharp V. Thus it is a cross between the U. S. standard thread and the sharp V-thread.

CADMIUM. Cadmium is one of the metallic chemical elements which shows a close relationship to zinc. Its chemical symbol is Cd, and its atomic weight, 112.4. The specific gravity of the pure metal is 8.56, but the commercial metal has a specific gravity of 8.6, on account of the greater density due to hammering. Cadmium resembles tin in color and general appearance. It does not occur free in nature, but is commonly found associated with zinc in zinc-blende and other zinc ores, and the commercial metal is obtained from the smelting of zinc ores. It is obtained mainly from Silesia and Belgium. Its most important use is in combinations with such metals as lead, tin, and bismuth with which it forms alloys that fuse at very low temperatures. One of these alloys, containing 50 per cent of bismuth, 25 per cent of lead, 12.5 per cent of tin, and 12.5 per cent of cadmium, melts at a temperature of 149 degrees F. Cadmium sulphate is also used for making standard electric cells.

CADMIUM EFFECT ON COPPER. Copper wire containing a small amount of cadmium has a greater tensile strength and a higher resistance to abrasion than ordinary copper wire, while its electrical conductivity is reduced very little, or less than 1 per cent for each 0.1 per cent of cadmium. The tensile strength increases slowly with increasing cadmium content, until 0.6 per cent of cadmium is reached; beyond this point additions of cadmium cause very rapid increases in tensile strength. Copper wire with 1 per cent of cadmium has been subjected to a temperature of 260 degrees C. for thirty minutes without showing signs of softening. A cadmium-copper wire having 20 per cent greater tensile strength has also 75 per cent greater resistance to breaking after repeated bendings than pure copper wire. In tests made with trolley wires under working conditions, the loss in diameter after eight months' use was less than one-third that recorded for pure copper wire.

CADMIUM SOLDER. Cadmium solders may be used for soldering tin plate, terneplate, brass, and copper, according to an investigation made by the Bureau of Standards. Four different compositions of cadmium solders have been tried: (1) Lead, 90 per cent; cadmium, 10 per cent; (2) lead, 80 per cent; cadmium, 10 per cent; tin, 10 per cent; (3) lead, 85 per cent; cadmium, 10 per cent; tin, 5 per cent; (4) lead, 75 per cent; cadmium, 10 per cent; tin, 15 per cent. The manufacture and use of the alloy first mentioned is rather difficult, because it oxidizes easily in the molten condition. The best composition is said to be that containing 80 per cent of lead and 10 per cent each of cadmium and tin.

CAESIUM. A rare, strongly basic metallic element, the chemical symbol of which is Cs, and the atomic weight, 132.8. It melts at 26 degrees C. (79 degrees F.), and has a specific gravity of 1.88. It is silver-white in appearance.

CALCINATION. The process of calcination is used in metallurgy for expelling, by means of heat, volatile matters with which metals are combined in their ores, thus reducing them, generally, to an oxide. The process is also frequently known as *roasting*. In the metallurgy of many of the most common metals, like copper, calcination or roasting is the first process to which the ore is subjected.

CALCIUM. Calcium is one of the metallic chemical elements. Its symbol is Ca, and its atomic weight, 40.1. Its specific gravity is 1.57, making its weight per cubic inch 0.057 pound. Calcium melts at a temperature of 810 degrees C. (1490 degrees F.). Its electrical conductivity (silver = 100) is 21.8. Calcium is a metal having a light yellow color and brilliant luster. It is about as hard as gold and is very ductile. It oxidizes rapidly in moist air, and burns at a red heat. A freshly cut surface of the metal closely resembles zinc in appearance, but when tarnished by exposure to the air it becomes yellow, and finally grayish-white. It combines directly with most elements, including nitrogen, and this is taken advantage of in forming an almost perfect vacuum. The metal is generally prepared by electrolysis. The most important industrial use of calcium is in the form of calcium carbide (CaC_2), which is the source of acetylene. Calcium carbide is manufactured by heating lime and carbon in the electric furnace.

CALCIUM CARBIDE. Calcium carbide (CaC_2) is a chemical composition of considerable industrial importance on account of the fact that it is used to produce acetylene gas through the action of water upon the carbide, and, hence, it is an important factor in the autogenous welding industry. Calcium carbide is produced in the electric furnace, the raw materials being lime and anthracite in the proportion of 100 parts, by weight, of lime to 68 parts, by weight, of anthracite. About 1.8 pound of this mixture is required to produce one pound of calcium carbide. Two processes are in use for producing the compound by means of the electric furnace, one being known as the *ingot* process and the other as the *tapping* process.

Ingot Process. — In the ingot process, the lime and anthracite in the proportions mentioned are ground and well mixed together, then an arc is struck in the crucible in which the compound is to be formed, and the mixture of lime and anthracite is permitted to flow into the crucible until it is partially filled. An ingot of calcium carbide is gradually formed at the bottom of the crucible, and the carbon electrode producing the arc is raised from time to time. The crucible in which the action takes place is made of metal, suitable precautions being taken in the arrangement to protect the crucible from intense heat. The principle of the process is that the lime and anthracite is heated only to the point of combination. The ingot of calcium carbide formed in the furnace is surrounded by a crust containing certain propor-

tions of imperfectly converted constituents, which does not produce acetylene gas with the same efficiency as the center core or ingot of pure calcium carbide. This outside crust is therefore, removed by sand blasting from the ingot.

Tapping Process. — In this process a crucible lined with carbon is used. The carbide is heated until it is fully fused, and is then tapped at short intervals from the crucible. All the material is converted into calcium carbide, and the plant required for the production by this process is cheaper than that required for the ingot process. The calcium carbide produced in this manner, however, is not as pure as the ingot carbide, because of an excess of lime which is nearly always present. This excess lowers the efficiency of the calcium carbide as regards its gas-producing power. The calcium carbide, as produced by the electric furnace, has a semi-metallic appearance with a specific gravity of 2.2. It remains unaffected by fully dry air, but any moisture in the atmosphere immediately produces small quantities of acetylene gas, and, therefore, gives the calcium carbide a distinctive odor.

CALCIUM CARBONATE. This is commonly known as "carbonate of lime," and is found generally in the form of limestone, marble, or chalk. Its specific gravity is 2.8. When contained in the feed water for boilers, it forms a soft mud in the boilers, unless cemented into a scale by the presence of calcium sulphate. It also forms a hard scale in economizers when the water is at a comparatively low temperature. It is soluble in water containing carbon dioxide, and is more easily dissolved in cold than in hot water.

Calcium carbonate, also known as *whiting*, is used for paints for the protection of iron and steel against corrosion. It is extensively used in paints, partly because it neutralizes any free acid that may be present in the linseed oil. When produced by artificial means, it generally contains impurities, requires more oil for grinding, and has not a high protective value.

CALCIUM CHLORIDE. A compound which, when present in boiler feed water, has a corrosive effect and which is one of the causes of *pitting* in boilers.

CALCIUM LIGHT. A very intense white light produced by two streams of gas, one of oxygen and one of hydrogen, impinged upon lime, while ignited.

CALCIUM SULPHATE. Calcium sulphate, more commonly known as *gypsum* or *plaster-of-paris*, is a sulphate of lime soluble in water free from carbonic acid at moderately low temperatures. When present in boiler feed water, it causes a hard scale difficult to remove. Mixed with mud or the sludge from *calcium carbonate*, it also forms a hard scale. Calcium sulphate

is widely used in the making of paints, but its use should be avoided in paints used for the protection of iron and steel against corrosion, because it is somewhat soluble in water and has a tendency to be washed off, and may, for this reason, even promote corrosion.

CALIBRATION. Calibration, in its mechanical sense, denotes an accurate comparison of any measuring instrument with a standard, and more particularly the determination of the errors of a scale used in a measuring device. The method used in calibrating any measuring instrument is generally divisible into two parts, of which one or the other may often be omitted. The first step is to determine the value of the unit to which the measurements are referred, by comparison with a standard unit of the same kind. This part is known as the " standardization " of the instrument, or the determination of a " reduction factor." The second step consists in the verification of the accuracy of the subdivision of the scale of the instrument, which is the actual calibration of the scale, and which does not necessarily involve a comparison of the instrument with any independent standard, but merely a determination of the relative accuracy of the graduations. In many cases, the process of calibration consists of a comparison of the instrument to be tested with a standard, covering the whole range of the graduations on the standard, the relative values of the subdivisions of the standard itself having been previously tested.

The usual method of calibration is the direct comparison of an instrument with a standard over the whole range of its scale. The standard itself should be previously calibrated so that its accuracy, or the amount of its errors, is known. The term " calibration " refers not only to measurements of length, but to measurements of all other engineering units; thus, for example, ammeters, voltmeters, pyrometers, dynamometers, and all other measuring instruments, are calibrated by a comparison with a standard.

CALIDO. Calido is an alloy containing nickel and chromium and a small quantity of iron, which is used for resistance wire in electrically heated devices on account of the fact that it can be subjected to high temperatures without losing its resisting qualities. Its maximum working temperature is about 1100 degrees C. (about 2000 degrees F.). It melts at about 1550 degrees C. (about 2800 degrees F.).

CALIPER, GEAR TOOTH. See Gear Tooth Caliper.

CALIPERS. Calipers are measuring tools used for taking measurements in machine work, and employed especially for measurements not requiring great accuracy. The ordinary machinist's calipers consist simply of two arms or legs joined with a pivot at one end and provided with points at the other end suitable for the kind of measurement, whether external or internal,

that is to be made. Measurements are taken by comparing the caliper setting with the graduations of a scale.

CALITE. Calite, an alloy containing iron, chromium, nickel, and aluminum, is the result of experiments conducted by metallurgists of the General Electric Co., for the purpose of finding an alloy that would withstand high temperatures, could be quenched repeatedly, and would be highly resistant to oxidation. Annealing boxes made from calite have been run for 1500 heat-hours without warpage, growth, or failure. The metal runs freely when molten, and any casting which can be made of steel can also be produced from this alloy. Sections as low as $\frac{3}{16}$ inch in thickness have been successfully cast. Calite cannot be machined in the cast condition nor cut with an oxyacetylene torch; hence, it must be finished by grinding.

This alloy is said to resist oxidation up to about 2375 degrees F., but a working temperature of 2200 degrees is recommended. Calite is practically non-corrosive, samples having been polished and subjected to a spray of saturated sea-salt solution at 100 degrees F. for 200 hours without any effect on the polish. The physical properties are: Melting point, 2780 degrees F.; softening temperature, 2500 degrees F.; specific gravity, 7.03; weight per cubic inch, 0.25 pound; and tensile strength, 36,800 pounds per square inch.

CALITE ALLOYS. The Calite alloys are a group of heat-enduring alloys available in the form of castings, sheets, shapes and forgings with particular reference to commercial requirements. Calite "A" is a nickel-chromium alloy available in cast form only and intended for general heat-enduring applications up to maximum metal temperatures of 2000 degrees F. The metal is readily machineable and entirely resistant to corrosion in contact with the ordinary products of combustion. Calite "B" is a nickel-chromium-aluminum alloy available in cast form only and intended for heat-enduring applications up to maximum metal temperatures of 1800 degrees F. This alloy was developed for the fabrication of beams and other parts required to sustain a load at high temperatures. It is unique in its quality of extreme stiffness at all temperatures up to the maximum safe working limit. The alloy is entirely resistant to corrosion in contact with the ordinary products of combustion. It can not be machined. Calite "E" is a malleable nickel-chromium alloy available in the form of castings, sheets, shapes and forgings. In addition to immunity from oxidation up to maximum metal temperatures of 1800 degrees F., it is not affected by weather corrosion, sulphur compounds and many organic acids and inorganic salts. The alloy finds wide application in sheet form. Sheets may be readily flanged, punched or welded. The welding operation may be successfully performed either with gas or electric arc. Calite "N" is a nickel-chromium alloy available in both cast and rolled form. The alloy is immune to oxida-

tion up to maximum metal temperatures of 2000 degrees F., its chief application being in sheet form. Calite " S " is a malleable chromium-iron alloy available in the form of castings, sheets, shapes and forgings. In addition to immunity from oxidation up to maximum metal temperatures of 1650 degrees F., it is not affected by weather corrosion or by corrosion in contact with nitric acid, sulphur compounds, alkaline solutions and many organic acids. The alloy finds wide application in sheet form.

CALKING. The riveted joints of steam boilers and other vessels which subjected to pressure are made tight by "upsetting" and compressing the metal along the edges of the joint, which operation is known as *calking* The calking tool by means of which the material is compressed is either operated by a pneumatic hammer or, if such a tool is not available, it is struck repeatedly by a hand hammer. As the edge is driven back and upset, the lap extending beyond the rivet is sprung somewhat and reacts against the lower plate with sufficient intensity to prevent the gas or fluid under pressure from passing the calked edge. The calking end of the tool used is rounded, and the radius of curvature should be somewhat proportional to the thickness of the plate to be calked, the radius increasing as the thickness of the plate increases. The edge of a plate that is to be calked should be fairly smooth and even, and should also be slightly beveled so that the lower edge which is next to the seam projects out somewhat. The angle to which the edge is beveled, varies in different shops, and, in some places, it is gaged merely by the eye, whereas, in others, templets are used. This angle, as measured from the inner or joint side of the sheet, usually varies from 75 to 80 degrees. The heavier forms of pneumatic hammers are recommended for calking, in order to secure heavy blows and a more solid connection between the two sheets.

CALORIE. The metric unit of quantity of heat, also known as the *French thermal unit*, or the *kilogram calorie*, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram calorie = 3.968 British thermal units. One British thermal unit = 0.252 calorie. The British thermal unit (B.T.U.) is the quantity of heat required to raise the temperature of one pound of pure water one degree F.

CALORIFIC VALUE OF FUEL. See Combustion of Coal.

CALORIMETERS. Calorimeters are of two kinds, fuel calorimeters and steam calorimeters. Fuel calorimeters are used for determining the heating value of fuels. Steam calorimeters are used for determining the percentage of moisture in steam. A *fuel calorimeter* consists mainly of a closed chamber in which a previously weighed sample of the fuel can be rapidly and com-

pletely burned. A receptacle containing a predetermined amount of water surrounds this chamber, so that the heat produced by the combustion of the fuel is transferred to the water. A sensitive thermometer is then used for measuring the rise in temperature of the water. Special means must be provided for igniting the fuel, and provision must be made for preventing loss of heat from the calorimeter by radiation or by the escape of the heated gases of combustion. The most commonly used calorimeter is that known as a " bomb calorimeter," also called " Mahler's modification of Berthelot's calorimeter."

Steam calorimeters are constructed in a number of different ways; one of those most commonly used consists of a half-inch pipe closed at one end and perforated with several $\frac{1}{8}$-inch holes in its walls. This pipe is inserted into the main steam pipe so that the steam can enter through the small holes. The other end of the pipe is throttled by an orifice $\frac{1}{16}$ inch in diameter, through which the steam escapes into a chamber having an outlet to the atmosphere. The temperature and pressure of the steam on each side of the orifice are then observed. The action of the instrument depends upon the fact that the heat of saturated steam increases with the pressure, and, consequently, if the pressure is reduced by the throttling effect of the orifice, the heat liberated will convert the moisture into steam and produce superheating. The steam in the chamber mentioned is superheated according to the amount of moisture contained in the steam passing into the half-inch pipe from the main steam pipe.

CALORIMETRIC PYROMETERS. In calorimetric pyrometers, the total heat absorbed by a metal — platinum, in the laboratory, and nickel or copper, in industrial works — is used to indicate the temperature. This was an early form of pyrometer.

CALORIZING. Calorizing is a process for covering metals with a layer of alumina, so that the metal can be heated to a comparatively high temperature — dull red heat — without oxidizing and deteriorating. Calorizing is used, among other things, for copper soldering irons, and for iron resistance wires for electric heating devices. It is intended only for protection at high temperatures and does not take the place of galvanizing, sherardizing, or similar processes for the protection of iron against oxygen or corrosion at low temperatures. Its usefulness lies within a range of temperatures which are much higher than those to which a galvanized or sherardized coating could be exposed.

CAMELIA METAL. A bearing metal composed of 70 per cent of copper, 15 per cent of lead, 10 per cent of zinc, 4.5 per cent of tin, and 0.5 per cent of iron is known as " Camelia " metal. It belongs in the same class as Ajax plastic bronze and brasses used for railroad car bearings.

CAMOGRAPH. "Camograph" is the trade name given to one type of machine for mechanically guiding an oxy-acetylene cutting torch. This machine is intended for use in boiler shops and fabricating plants, to provide a means of cutting hand-holes and other openings in boiler sheets, ship plates, tanks, drums, etc. Provision may be made for cutting various shaped openings by substituting the proper cams on the machine.

CAMS. Many machine parts require either an intermittent or an irregular motion. The most common method of obtaining an irregular motion is by means of cams which have grooves or surfaces of such shape or form that the required motion is imparted to the driven member when the cam is in motion. The exact movement derived from any cam depends upon the shape of its operating groove or edge which may be designed according to the motion required.

Cams may be classified according to the relative movements of the cam and follower and also according to the motion of the follower itself. In one general class may be included those cams which move or revolve either in the same plane as the follower or a parallel plane, and in a second general class, those cams which cause the follower to move in a different plane which ordinarily is perpendicular to the plane of the motion of the cam. The follower of a cam belonging to either class may either move in a straight line or receive a swinging motion about a shaft or bearing. The follower may also have either a uniform motion or a uniformly accelerated motion.

The working edge or groove of a uniform motion cam is so shaped that the follower moves at the same velocity from the beginning to the end of the stroke. Such cams are only adapted to comparatively slow speeds, owing to the shock resulting from the sudden movement of the follower at the beginning of the stroke and the abrupt way in which the motion is stopped at the end of the stroke. If the cam is to rotate quite rapidly, the speed of the follower should be slow at first and be accelerated at a uniform rate until the maximum speed is attained, after which the motion of the follower should be uniformly decreased until motion ceases, or a reversal takes place; such cams are known as "uniformly accelerated motion cams."

Types of Cams. — Cams may be divided according to their mechanical construction, into three different types, plate cams, face cams, and cylinder cams. *Plate cams*, also known as *disk* or *peripheral cams*, are those cams which consist of a flat disk, and on which the follower operates against the outside or peripheral surface of the disk. A well-known type of this form is the *heart cam*, so called because of its peculiar shape. The *face cam* also consists of a flat disk, but the follower, instead of operating against the outside periphery of the disk, engages a groove cut into the flat surfaces of the

cam. *Cylinder cams*, also known as *barrel cams* are cylindrical in shape; the follower engages a groove cut into the cylindrical surface of the cam. Either of these types of cams may be designed to produce a uniform or a uniformly accelerated motion, or may produce any irregular motion required. The type of cam, as regards uniformity of motion, depends upon the dynamic conditions; but the form of cam, whether a plate cam, face cam, or cylinder cam, depends entirely upon the designer's judgment as to the best mechanical means for obtaining the desired movement. See Gravity Curve; Harmonic Motion Curve.

CAMS, GRINDING. The cams used on gas and gasoline motors, for operating the inlet and exhaust valves, are finished to the correct form by grinding. This grinding may be done in a regular cylindrical grinding machine by using a suitable cam-grinding attachment. The general method of grinding cams is by so mounting the cam or camshaft that, while rotating, it will be moved toward and from the grinding wheel by a master cam, the movement causing the cam to be ground to the required form or contour. The master cam is in engagement with a roller which transmits motion to the work-holding fixture. It is evident that cam grinding first involves the generation of master cams, since these must be made to suit each different form of cam that is ground.

CAMS, MILLING. Most cams are milled by using either an attachment on a milling machine or a special cam-cutting machine, the arrangement in either case being such that the contour of a master cam or templet serves to control the curvature of the cam groove that is milled. The curvature of the master cam groove or templet may or may not be an exact duplicate of the cam that is cut, as this depends upon the design of the cam-cutting mechanism.

Cam Milling Machine. — Cam or form milling machines operate on the same general principle as an ordinary profiling machine, although the construction is different. When a machine of this type is in operation, a pen or roller bears against a former plate or model and, as the work table revolves, the cutter is caused to move so as to reproduce the required outline on the work. The master cam is rotated in whichever direction presents the least abrupt angles for the roller and cutter to pass over. For instance, if a cam were being milled having a sudden rise at one point, the direction of rotation should be such that the former pin will approach the rise from that side which has the most gradual ascent.

CANADIAN CORUNDUM. A natural abrasive containing from 90 to 95 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. As an abrasive it is much better than emery, containing less iron oxide, which is the most objectionable impurity. Canadian corundum is

mined in eastern Ontario, where there are very large and practically inexhaustible deposits.

CANDLEPOWER. The lighting effect of a source of light is measured or expressed in candlepower. A " candle " is the unit of light intensity recognized by the national laboratories or bureaus of standards in the United States, France, and Great Britain, as well as in many other countries. Distinction is made between the *mean horizontal candlepower* of a lamp, which is the average candlepower in a horizontal plane passing through the luminous center of the lamp when mounted in the usual manner, as, for example, in the case of an incandescent lamp with its axis of symmetry vertical; the *mean spherical candlepower* of a lamp, which is the average candlepower of the lamp in all directions; and the *mean hemispherical candlepower* of a lamp, which is the average candlepower of the lamp in either the upper or the lower hemisphere. It is customary to rate incandescent lamps on the basis of their mean horizontal candlepower.

CANT-FILE. Cant-files and cant-saw files are files of triangular cross-section, and differ in cross-section as to their angles; the cant-file has 30, 30, and 120 degree angles and the cant-saw, 35, 35, and 110 degree angles. The cant-saw shape was formerly known as " lightening." It is used principally for filing cross-cut saws having N-shaped teeth.

CANTILEVER. A cantilever is a beam which is supported or held firmly at one end and which projects from its support so that the outer end is free and unsupported. Each half of a cantilever bridge, for example, is wholly supported from the abutments and towers at the ends of the span, and the arms that reach out from the towers do not, in any way, depend upon their connection with each other at the center to increase their carrying capacity. They are merely connected, but each arm or cantilever is so proportioned that it is able to carry the load on the bridge independently of the remainder of the structure.

CAPACITY. The expression " capacity " is used in a number of different meanings in science and engineering. The capacity for heat is the amount of heat required to raise the temperature of an object one degree; hence, the capacity for heat is equal to the product of the mass or weight of an object by its specific heat. Sometimes the capacity for heat is expressed in terms of the amount of water which would be raised one degree by the amount of heat in question.

In electrical engineering, capacity is used in the terms *power capacity* and *current capacity*, referring to the power or the current which a device can safely carry. The temperature rise in a conductor due to heat developed when an electric current flows through it, is one of the limiting factors of the current-carrying capacity of a conductor.

Capacity is also used when referring to the electrostatic capacity of a device, but it has been recommended by the American Institute of Electrical Engineers that, when used in this sense, the term *capacitance* be used instead. The capacity or capacitance of an alternating electric circuit is the measure of the amount of electricity held by it when its terminals are at unit potential. A condenser is said to have unit capacity, if unit current existing for one second produces unit difference of potential at its terminals. The practical unit of capacity is that of a condenser in which one ampere during one second produces one volt difference of potential; it is called a *farad* One farad is an extremely large capacity, and, therefore, one-millionth of one farad, called *micro-farad*, is commonly used. The effect of capacity is directly opposite to self-induction.

The capacity of an air compressor equals the amount of *free air* in cubic feet which may be compressed to a given higher temperature in a unit of time.

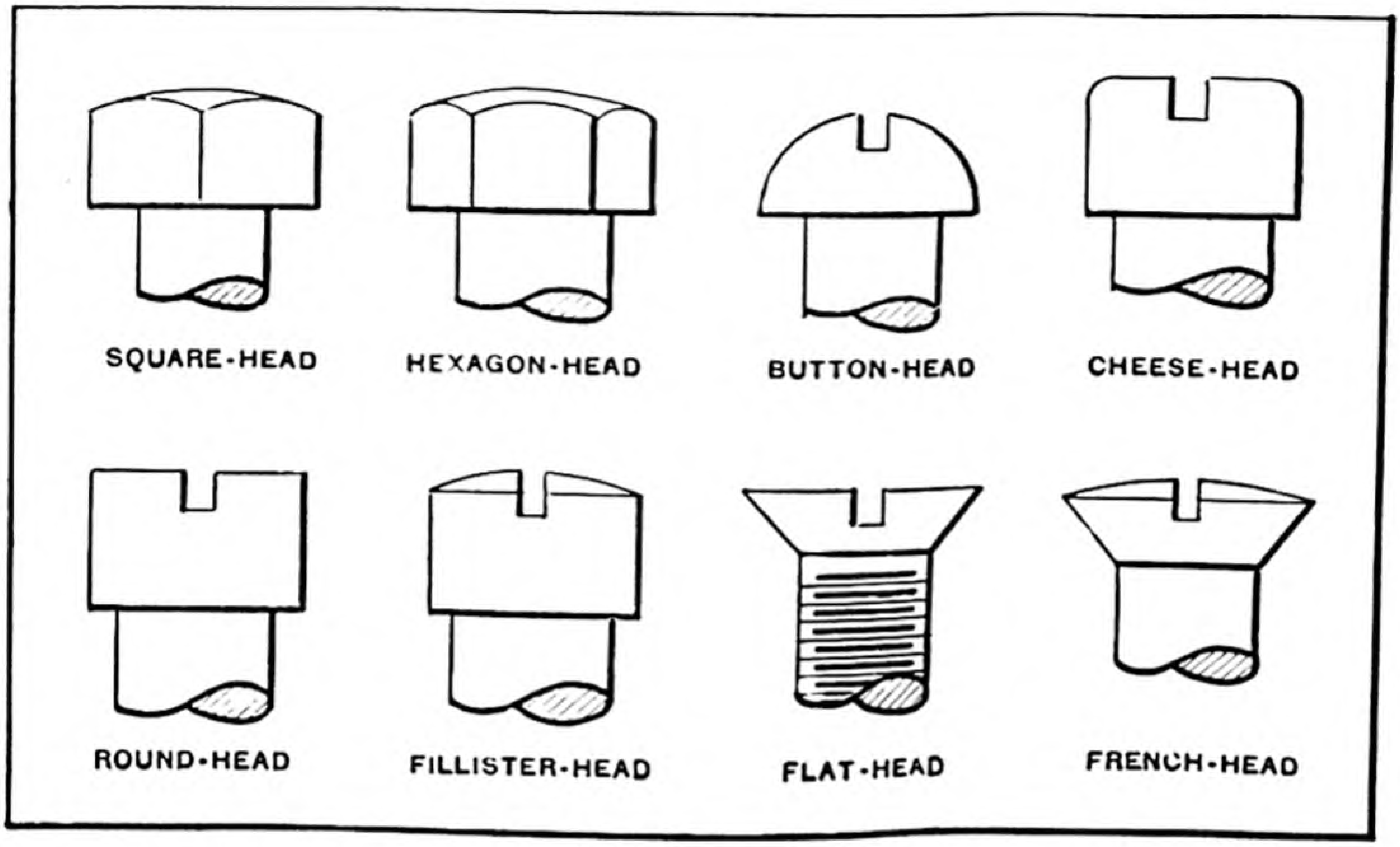
CAPE CHISEL. A form of cold chisel having a narrow blade for the cutting of grooves or keyways.

CAPILLARY ACTION. When a tube of glass, the bore of which is very small in diameter and which is open at both ends, is placed vertically with its lower end immersed in water, the water will rise in the tube and will reach a higher level on the inside of the tube than the level of the water outside. The force or action which makes the water rise higher inside of the small-diameter tube is known as "capillary action." The same name is used for many other phenomena observed in the properties of liquids when spread over surfaces. Capillary actions are explained by reference to surface tension, cohesion, and adhesion between the molecules, etc. Capillary action is of importance in many devices used for lubrication, the oil rising against gravity along a wick and thereby reaching the surface to be lubricated.

CAP-SCREW. Cap-screws are inserted in tapped holes like machine screws, but they are made in larger sizes and are generally used for heavier work. Cap-screws have solid heads like machine screws, but, ordinarily, these heads are either hexagonal or square and are intended to receive a wrench instead of being slotted for a screw driver. The term "tap-bolt" is also applied to screws of this class. The nominal length of a cap-screw is the length measured under the head.

CAP-SCREW NAMES. Different forms of cap-screws and the names used to designate them, are included in the accompanying diagram. Some cap-screws have heads which are similar in shape to machine screw heads, although the names ordinarily applied are not the same. For example, a

" flat fillister-head " machine screw is the same as a " round " cap-screw, and a " round-head " machine screw is similar to a " button-head " cap-screw. An " oval fillister-head " machine screw is like a " fillister-head " cap-screw. Machine- and cap-screws having countersunk heads are both known as " flat head " screws.



Names of Cap-screws

CAP-SCREW THREADS. Most cap-screws have the U. S. standard thread, with 13 threads per inch for ½-inch diameters, although 12 or 13 threads per inch is usually listed in the catalogues of screw manufacturers, indicating that cap-screws of ½-inch size will be cut to whichever pitch is ordered. According to a common rule, the length *E* of the thread is determined as follows: For cap-screw lengths *L* of 4 inches or less, the length of thread *E* equals ¾ of length *L*; for lengths *L* greater than 4 inches, *E* equals ½ of *L*. S.A.E. cap-screws have the U. S. form of thread, but a finer pitch for the same diameter than the U. S. standard.

CAPSTAN LATHE. In England, turret lathes are often called *capstan lathes*. The terms " *capstan* " and " *turret*," however, are sometimes used interchangeably, although many firms observe a sharp distinction in their application, in that they apply the name " capstan " only to those machines which have a slide moving in a saddle that is bolted down to the bed, whereas the name " turret " is used when the turret-slide is mounted directly on the bed. The effective difference between the two designs is that the working stroke of the first one is limited by the movement of the turret-slide in the saddle, whereas, with the second arrangement, the longitudinal feed-

ing movement of the turret is limited by the length of the bed. See Turret Lathe Classification.

CARAT. In reference to gold, a carat is an indication of how many 24ths of an alloy is pure gold. For example, 18-carat gold is an alloy containing $\frac{18}{24}$ pure gold and $\frac{6}{24}$ of other alloying metals. A carat is also a unit of weight used for diamonds and precious stones. The international carat, adopted 1905, and since then made standard in most European countries and, on July 1, 1913, in the United States, equals 200 milligrams or 3.086 grains troy. The South African carat is 3.174 grains. The old carat, standardized in 1877, was 205 milligrams or 3.163 grains troy.

CARBALON. A trade name for an abrasive used for making grinding wheels. Carbalon is produced from coke and sand in the electric furnace. It is especially suitable for grinding materials of low tensile strength.

CARBIDE GENERATOR. See Water-carbide Generator.

CARBIDE OF SILICON. A compound of silicon and carbide having the chemical formula SiC. See Abrasives.

CARBO-ALUMINA. An artificial abrasive, which is used in the manufacture of wheels for grinding materials of high tensile strength, is known as *carbo-alumina.* This abrasive is produced from the mineral bauxite in a manner similar to that of alundum.

CARBOLITE. Carbolite is the trade name for an artificial abrasive produced in the electric furnace. It is composed of carbide of silicon. Like other abrasives belonging to this class, it is adapted more particularly for grinding the softer metals, such as cast iron and brass. It is also used for grinding rubber, leather, pearl, marble, granite, and similar materials. Carbolite is hard and sharp, but not tough as compared with an abrasive like corundum. On the other hand, it is quite brittle and, therefore, is adapted especially for grinding materials of low tensile strength.

CARBOLON. Carbolon is used in making wheels for grinding materials of low tensile strength. Carbolon is produced from coke and sand in the electric furnace. It has been found that an accurate control of temperature in the reaction zone of the furnace is of the utmost importance, and, also, that the slightest variation in the mixture of raw materials produces a marked effect on the nature of the resultant crystalline mass.

CARBON. In nature, carbon is found free in two forms, as the diamond and as graphite; in combination with other elements carbon enters as a constituent of practically all animal and vegetable compounds, and of coal and petroleum. The specific gravity of carbon in the form of diamond is 3.5. When found as graphite, the specific gravity is about 2. Charcoal is also a

porous form of nearly pure carbon. The properties of carbon vary according to the form in which it is found; thus, for example, the specific heat of diamond at 10 degrees C. (50 degrees F.) is about 0.11; of graphite at the same temperature it is about 0.16; and of wood-charcoal, 0.17. Besides the industrial uses of carbon in the form of graphite and charcoal, it is the chief constituent of all combustible materials, and is one of the most important of the chemical elements in its combination with other elements. The carbon content of steel, for example, determines to a very large extent its characteristics. In fact, the distinction between wrought iron, mild steel, tool steel, and cast iron is due mainly to the different percentages of carbon contained in the metal.

CARBONATE OF LIME. Same as *calcium carbonate*

CARBONATE OF SODA. Same as *sodium carbonate.*

CARBON-BREAK CIRCUIT-BREAKER. A device for automatically opening an electric circuit, so arranged that the arc is broken in the air between carbon blocks. Carbon is used because it withstands the heat of the arc without being destroyed, and the carbon contacts will not "freeze" together.

CARBON DIOXIDE. A compound of carbon and oxygen, the chemical formula of which is CO_2.

CARBONIA FINISH. A carbonia finish consists of a method of coloring iron and steel surfaces with any of the temper colors that are obtainable by heating steel to different temperatures. The operation is carried out in a rotary gas furnace; the finish produced has a high luster.

CARBONIC ACID. Same as *carbon dioxide.*

CARBONIZING. A term often applied erroneously to carburizing. See Carburizing.

CARBON REGULATOR. An electrical machine employed for the charging of storage batteries. Also known as *Entz booster.*

CARBON STEEL. The expression "carbon steel" is often applied to tool steel containing no alloying metals, the term being used to distinguish such steel from alloy steels which contain tungsten, nickel, chromium, or other metals. These alloy steels also contain carbon and many to the same extent as "carbon steel"; hence, this expression is not strictly correct in a chemical or metallurgical sense. The carbon content in steel is generally expressed by giving the percentage of carbon as, for example, 0.90 per cent carbon steel. This is also often expressed as "90-point" carbon steel.

Carbon "Points" in Steel.—The point system used in specifying the carbon content of steel is based on the division of one per cent into one hundred

parts; hence, "10 points carbon" means one-tenth of one per cent carbon and not 10 per cent. To express the carbon content in percentage in the case, say, of 50-point carbon steel, the expression should be "one-half per cent" carbon. The term "points" probably originated in an inversion of the reading of the decimal of one per cent; the decimal 0.40, for instance, was read "40-point" instead of "point 40" in order to emphasize.

Carbon Temper of Steel. — The carbon temper of steel is a term applied by steel makers to indicate the proportion of carbon in the steel, the temper marks or numbers being arbitrarily selected so that their relation to the percentage of carbon varies with different makers. According to one system, the temper number indicates approximately the number of tenths of the carbon percentage; for example, No. 8 carbon temper designates steel containing about 0.80 per cent of carbon, while No. 14 carbon temper designates steel containing about 1.4 per cent of carbon.

CARBON STEEL APPLICATIONS. Steel with a carbon content of from 0.65 to 0.80 per cent is suitable for shear blades, boiler snaps, and cups, hammers, stamping and pressing dies, and mining drills. Steel with a carbon content of from 0.81 to 0.95 per cent is suitable for hot and cold sets, chisels, dies, shear blades, mining drills, blacksmiths' tools, swages, flatteners, and set-hammers. Steel with a carbon content of from 0.96 to 1.10 per cent is suitable for small cold chisels, hot sets, small shear blades, large pincers, large taps, granite drills, trimming dies, turning tools, planer tools, drills, cutters, slotting and milling tools, mill picks, circular cutters, small shear blades, and threading dies. Steel with a carbon content of from 1.11 to 1.25 per cent is suitable for small milling cutters, small taps, drills, slotting and planing tools, wood-cutting tools, turning tools, and razors.

The best all-around tool steel contains from 0.90 to 1.10 per cent of carbon, and can be adapted to a wider range of uses than any other grade. For tools, generally, it gives the highest strength together with a high degree of hardness when heat-treated. It cannot, however, be welded easily. Steels containing up to 1.50 per cent of carbon are easily burnt, and are welded only with great difficulty. They can, however, be hardened to an extreme hardness.

CARBON TEMPER. See under Carbon Steel.

CARBON STEEL HEAT-TREATMENT. See Heat-treatment of Carbon Steel.

CARBORUNDUM. Carborundum is an abrasive which is produced artificially in the electric furnace; it is a chemical combination of the two elements, carbon and silicon, *carborundum* being a trade name. The principal materials used in the manufacture of carborundum are coke, which

supplies the carbon element, and sand, which supplies the silicon. The coke is crushed in a mill and is then mixed with the sand. To the mixture of sand and coke is added a quantity of sawdust, in order to make the mixture porous, thus allowing the gases to escape freely. After suitable treatment, the mass of raw material is placed in an electric furnace. The temperature of the surrounding mass of coke and sand is raised to a point between 7000 and 7500 degrees F. As the result of this high temperature, objectionable impurities in the coke and sand are destroyed or driven off in gaseous form, leaving only the carbon and silicon which unite, thus forming the abrasive, carborundum. The crystalline masses of carborundum are crushed and reduced to individual crystals or grains which are carefully washed, dried, and graded through screens of different mesh, thus obtaining different grade numbers.

CARBORUNDUM BRICKS. There are two kinds of carborundum brick furnace linings: one, the recrystallized or refrax, and the other the clay-bonded, or carbofrax. In the first type, by heating the material in an electric furnace at a temperature of 2000 degrees C., a brick is formed which is well bonded and which has a tensile strength of from 1500 to 2000 pounds per square inch. Carbofrax bricks are made by bonding carborundum with a small percentage of clay and burning at high temperatures. The result is a hard stiff brick, very resistant to abrasion and capable of withstanding high heat. The fact that carborundum has such a low coefficient of expansion readily reduces breaking off and chipping when the brick is subjected to sudden temperature changes; consequently the life of the brick is greatly prolonged. Carborundum bricks retain their mechanical strength even at high temperatures and in this respect differ from most refractories. Carborundum is unaffected by acid or by burning oil. It will not stand the action of molten iron or steel, however, and is also decomposed by alkali at high temperatures.

CARBOWALT. Carbowalt is the name of an abrasive which is manufactured from coke and sand in a manner somewhat similar to that of carborundum, and used for the making of grinding wheels.

CARBURETOR. The purpose of the carburetor of a gasoline engine is to introduce into the current of air, entering the cylinder of the engine, a proper quantity of gasoline in such a manner that it will be completely evaporated and thoroughly mixed with the air. The devices for forming an explosive mixture from gasoline and air may be divided into two distinct groups. In the *spraying* or *atomizing* type of carburetor, which is used on gasoline engines for automobiles, motor boats, etc., the necessary quantity of gasoline for each charge of the engine is atomized by a valve and then sprayed into the inrushing air, which process, especially when the air has

previously been heated, is so thorough that the mixture may be used immediately for charging the engine. In the *vaporizing* carburetor, which is the type largely used for stationary engines, the engine piston draws air directly through a gasoline storage tank, thus saturating it with gasoline vapor. Additional air must be drawn in before the vapor enters the engine cylinders, to form an explosive mixture.

CARBURIZING. Carburizing, often erroneously known as "carbonizing," is generally referred to in connection with casehardening of steel. Carburizing consists in adding carbon to the surface of low-carbon steel by heating the steel in contact with materials high in carbon. The steel absorbs a certain amount of carbon from the carbonaceous materials, and this increase in the carbon content of the surface of the steel makes it possible to harden the steel in a manner similar to that in which so-called "high-carbon" steel is hardened, that is, by heating to a red heat and cooling by quenching.

To harden low-carbon steel involves two separate operations: First, the carburizing operation for impregnating the outer surface with sufficient carbon, and second, the heat-treating of the carburized parts so as to obtain a hard outer case and, at the same time, give the "core" the required physical properties. The term *casehardening* is ordinarily used to indicate the complete process of carburizing and hardening, but it is often applied to indicate the heat-treatment after carburization.

CARBURIZING BY ROTARY METHOD. In carburizing by the rotary method, the work is contained in a slowly revolving retort, where it is heated and subjected to the action either of a carburizing gas or of a solid carburizer. The parts, when sufficiently heated, have an affinity for the carbon in the gas or in the carburizing material, as the case may be, and the slow rotation which exposes all surfaces, combined with accurate temperature regulation, insures uniform carbon penetration and comparatively rapid action. When a carburizing machine is supplied with the proper air and fuel conditions, its charge may be brought to a carburizing heat of 1650 degrees F. in from three-fourths to one hour's time, depending upon the size of the work. Actually carburization starts about the time the work reaches a low red heat. If heat controllers are used, it is customary and practical to start the computation of carbon penetration at the time that the heat controllers shut off the fuel.

The fuel ordinarily used for heating the work is gas, but oil may also be employed as the heating fuel. Gas is preferable, as it is cleaner, requires practically no burner attention, and auxiliary equipment, such as heat-controlling apparatus, storage facilities, etc., is less complicated and less expensive. Gas is also more flexible in regard to temperature variations.

The oil-fired machines are satisfactory, but much depends upon the manipulation of the burners. As one of the primary agents in gas for carburizing is the illuminants, and as these illuminants vary with the manufacture of gas, it is often found that the best results are obtained from solid carburizers. Any carburizing agent that is suitable for pack-hardening is satisfactory. Oil hydro-carbon materials may be objectionable on account of the smoke. Barium energized materials, and those containing less than 3 per cent sodium carbonate, are desirable. A powder material carburizes as fast as the same material in pill form.

CARBURIZERS. Carburizers may be classed by their physical form as follows: (1) Powder materials, in which the generator and the energizer are in a powder form and are thus mixed together. (2) Pill materials, in which the generator and the energizer are in a powder form, but are held together by a binder which in itself may be either a generator or an energizer. (3) Pellet materials, in which the generator is a granule of solid carbonaceous material coated with an energizer by the help of a binder. (4) Pellet and powder materials, in which the generator is a granule of solid carbonaceous material, and the energizer is in the form of a powder. A certain per cent of the powder may also be a generator. Different combinations of the above four forms may be found, but no great value should be attached to claims for their importance. Two other mediums are still used to some extent for carburizing, namely, bone and leather. Bone is classed as a pellet material, with the exception that the energizer is contained in the bone in the form of ammonium carbonate. The ammonia fumes are quite noticeable when water is poured on red hot bone. Leather is classed as a powder material due to its being so easily powdered. The energizer is in the form of cyanogen and is contained within the leather. Charcoal, coke and coal should not be classed as carburizers, as they are nothing more than generators. Alone, they are not easily controlled as regards penetration and percentages of carbon entering the steel to form the case. There are many commercial carburizers on the market in which the materials used as the generator may be hard and soft wood charcoal, animal charcoal, coke, coal, beans and nuts, bone and leather, or various combinations of these. The energizers may be barium, cyanogen, and ammonium compounds, various salts, soda ash, or lime and oil hydrocarbons. Sulphur and phosphorus are the two impurities that cause the greatest trouble in carburizing and are therefore the greatest drawbacks.

CARD PATTERN. A molding pattern with a number of individual patterns gated together so that several can be molded at once.

CARD-WEIGHT PIPE. A term used to designate standard or full-weight pipe, which has the standard thickness.

CARNOT'S FUNCTION. In thermo-dynamics, that function of temperature in Carnot's theory of heat which corresponds to the reciprocal of the absolute temperature.

CARRIAGE BOLT. A bolt having an oval head in cross-section, beneath which the bolt is square for a short distance. The other end of the bolt is threaded for about twice its diameter for a square nut.

CARTRIDGE BRASS. A brass suitable for the drawing of cartridge cases, containing 33 per cent of zinc and 67 per cent of copper.

CARTRIDGE FUSE. A cartridge fuse consists essentially of one or more strips of fusible metal enclosed in a fiber tube filled with a powdered insulating substance. This substance serves to absorb the heat liberated when the fuse is blown and condenses the vapor of the molten metal, breaking the continuity of the electric circuit.

CAR-WHEEL BORING MACHINES. The purpose for which boring machines of this type are intended is indicated by the name. There is a single vertical spindle located in alignment with the center of the circular work table, which has chuck jaws for holding the car wheels while boring them. The spindle is counterweighted either by a wire cable and weight or by a pivoted lever attached to the upper end and having an enlarged outer end the same as the counterweight of a slotter. These machines are sometimes equipped with a horizontal slide for facing the wheel hubs. They are very efficient for the limited class of work to which they may be applied.

CAR-WHEEL GRINDING. Car wheels in general have soft iron centers with deeply chilled treads. It is economy to grind new wheels to prevent difficulties that arise from wheels slightly out of round. Used wheels that have developed flat spots are economically salvaged by grinding. On one make of car wheel grinding machine, grinding wheels 24 inches in diameter by 4 inches thick are employed. The work in this case is not traversed but the grinding wheel is fed straight in, so that the entire surface of the tread is ground with the full width of the grinding wheel. The car wheels are usually not removed from their axles before grinding. During the grinding the car axles revolve on their journals rather than on centers. On this account some vibration takes place which tends to disintegrate the wheel structure, and this together with the very great pressures applied to hasten the grinding necessitates the use of very hard wheels.

CASEHARDENING. In order to harden low-carbon steel it is necessary to increase the carbon content of the surface of the steel so that a thin outer "case" can be hardened by heating the steel to the hardening temperature and then quenching it. The process, therefore, involves two separate opera-

tions. The first is the *carburizing* operation for impregnating the outer surface with sufficient carbon, and the second operation is that of heat-treating the carburized parts so as to obtain a hard outer case and, at the same time, give the " core " the required physical properties. The term " casehardening " is ordinarily used to indicate the complete process of carburizing and hardening, but it is often applied to indicate the heat-treatment after carburization.

For certain uses, steel parts are required to resist wear and at the same time to be sufficiently tough to withstand shocks. Toughness and hardness, however, are two qualities which do not appear at their maximum at the same time in steel. In machine construction, articles which must have a perfectly hard surface, and yet be of such internal structure that there is no chance of their breaking when in use, can be made to greater advantage from a mild steel which is casehardened than by using an expensive high-class crucible steel.

Casehardening Process. — In general, the casehardening process consists of packing steel articles made from a low-carbon steel in metal boxes or pots, with a carbonaceous compound surrounding the steel objects. The boxes or pots are sealed and placed in a carburizing oven or furnace maintained at a heat of from about 1650 to 1830 degrees F. for a length of time depending upon the extent of the carburizing action desired. The carbon from the carburizing compound will then be absorbed by the steel on the surfaces desired, and the low-carbon steel is converted into high-carbon steel at these portions, while the internal sections and the insulated parts of the object retain practically their original low-carbon content. The result is a steel of a dual structure, a high-carbon and a low-carbon steel in the same piece. The carburized steel may now be heat-treated by heating and quenching, in much the same way as high-carbon steel is hardened, in order to develop the properties of hardness and toughness; but as the steel is, in reality, two steels in one, one high-carbon and one low-carbon, the correct heat-treatment after carburizing includes two distinct processes, one suitable for the high-carbon portion or the " case," as it is generally termed, and one suitable for the low-carbon portion or core.

Rehardening. — The method of heat-treatment varies according to the kind of steel used. In general, quenching from the pot and again rehardening at a temperature of from 1400 to 1450 degrees F. will serve the purpose of refining the case to a great extent and will likewise bring out the natural qualities and toughness of the initial steel or core. Cooling in the pot, rehardening at about the critical temperature of the core, and quenching (the critical temperature being from about 1550 to 1650 degrees F., depending upon the original carbon content of the steel), and rehardening at the critical temperature of the case (1400 to 1450 degrees F.) will serve to refine the core

and case to the maximum extent. The result will be maximum toughness and grain refinement of core, and maximum toughness, grain refinement, and hardness of the case. The function of cooling in the pot is to allow the structure of the steel to come to rest, which helps to prevent warpage from internal strains.

Cyanide Bath. — Another method of casehardening is to immerse steel articles in a cyanide bath heated to about 1580 degrees F. This process is convenient and effective only on small articles and where the required depth is not more than from 0.005 to 0.015 inch, or where a mere surface hardening is wanted. This is a fast case-forming method, being accomplished in from ten to fifteen minutes. The outstanding disadvantage of this process is the impossibility of producing uniform cases. The parts that are deep in the melted bath do not receive the same depth of penetration as the parts near the surface because the evolution of the cyanide gases at or near the surface favors penetration.

Cyanide Process. — Casehardening may be done either by dipping a cherry-red piece of steel or tool into a container of powdered cyanide salt, such as potassium cyanide, sodium cyanide, or ferro- and ferri-cyanides, or sprinkling the powdered salt on the red-hot steel surface, and putting the steel back in the fire. The casehardening produced in this way is superficial, and resistance to excessive wear cannot be expected.

Gas Process. — In another method, carburizing gases are passed over a piece of steel heated in a retort. This process is applicable to parts that are intricate in design. The principle upon which this process is based is the casehardening of steel and iron-alloy articles in cyanogen gas evolved from a container filled with an alkali cyanide salt, heated by electrical energy or other means to accomplish the vaporization or boiling of the salt. The parts being treated are independently heated out of contact with the fused cyanide salt. The depth of penetration is a function of the uniformity of the temperature of the article treated and the duration of treatment. Nascent cyanogen gas has a speed of penetration of four or five times that of carbon monoxide. Sodium cyanide melts at 1112 degrees F. and boils at 1472 degrees F. Thus, the temperature of the pot must not be less than the latter, and to absorb this gas effectively, the steel must be at a temperature above the upper critical point, or about 1650 degrees F. See Nitrogen Hardening.

CASEHARDENING CARBURIZERS. See Carburizers.

CASEHARDENING STEEL. A low-carbon steel containing, say, from 0.15 to 0.20 per cent of carbon is suitable for casehardening. In addition to straight carbon steels, the low-carbon alloy steels are employed. They add to the parts the same advantageous properties for which they are em-

ployed in other classes of steel. *Nickel* is a valuable aid in producing a core which readily responds to refining and at considerably lower heats than in steel in which it is absent. In some cases results have been obtained by a single heat-treatment which compare most favorably with straight carbon steel, given two heats, one for case and one for core. The core resulting has a fine grain and is extremely tough. *Chromium* gives a very fine grain to case and core and imparts additional hardness in conjunction with the carbon. It has, however, when present in an amount much over 0.25 per cent, a tendency to render the core less tough, especially in steels around 0.20 per cent carbon, or higher. *Chrome-nickel* steels containing both of these elements give very good results. They give very fine-grained parts after heat-treatment, and can be treated at a considerably lower temperature than straight carbon steels.

CASEIN GLUE. See Glues for Wood.

CASING THREAD, OIL-WELL. See Oil-well Casing Thread.

CASTING, CENTRIFUGAL. See Centrifugal Casting.

CASTING IN PERMANENT MOLDS. A method for making castings by the use of what is termed permanent molds, is known as the *Custer process*. The molds are made of metal, and, hence, of a permanent nature, as compared with sand molds which disintegrate after each casting is made. The permanent molds should be made of a soft cast iron fairly high in silicon and graphite carbon, and low in combined carbon. A cast iron used for permanent molds is as follows: Combined carbon, 0.84 per cent; graphite carbon, 2.76 per cent; silicon, 2.02 per cent; sulphur, 0.07 per cent; phosphorus, 0.89 per cent; and manganese, 0.29 per cent.

The reason that it is possible to produce soft castings in a permanent metal mold is due to the fact that a certain time elapses between the point at which the molten metal will set and the temperature at which it will begin to chill. This interval is long enough to give the operator of the mold time to remove the casting from the mold before chilling begins. At this time the casting is still at a bright red heat, but the sudden contact with the cool surfaces of the mold has made the surface of the casting sufficiently hard so that it can be handled without fear of distortion or breakage.

"CASTING-ON" OR "BURNING-ON." See "Burning-on" or "Casting-on."

CASTINGS. See Aluminum Castings; Aluminum Alloys for Automobile Parts; Annealing Malleable Iron Castings; Brass Alloys for Castings; Gear Castings, Bronze; Cast Iron; Chilled Castings; Cold-pressed Castings; Copper Castings; Malleable Castings; Steel Castings.

CAST IRON. According to the specifications adopted by the International Association for Testing Materials, *cast iron* is defined as iron containing so much carbon that it is not malleable at any temperature. To conform to this definition, iron containing more than 2.2 per cent of carbon is classified as cast iron. Generally, commercial cast iron, however, has a carbon content of between 3 and 4 per cent. This carbon may be present as graphite, in which case the iron is known as *gray cast iron*, or it may be present in the form of cementite or combined carbon, in which case the iron is known as *white cast iron*. In most cases, however, carbon is present partly as graphite and partly as cementite. Besides carbon, silicon, sulphur, manganese, and phosphorus are nearly always present in cast iron.

Graphitic Carbon. — Graphite is merely mixed with the iron instead of being in chemical combination. Since it is only mixed with the metal, it cannot exert any direct influence upon the properties of the molecules of the iron. So far as the graphite itself is concerned, the toughness, hardness, and melting point of the grains of the iron will not be altered. The tensile strength will, however, be greatly affected, since the interposition of the flakes of graphite will act as partings between the grains of the metal and reduce the cohesion. Iron high in graphite is soft, and can be machined readily, but is of low tensile strength.

Combined Carbon. — The carbon which is in chemical combination affects directly and greatly the properties of ordinary cast iron. It is the principal factor in determining the hardness, tenacity, soundness, and freedom from internal stresses of the castings. In general, the percentage of combined carbon ranges from 0.05 in the softest cast iron to about 0.60 in iron of the highest strength. With suitable iron mixtures, the amount of silicon and sulphur present regulates the separation of carbon as graphite, so that the amount of silicon present is an index of the relation between the free and combined carbon. When the graphitic carbon is in excess, the fracture is grayish in color and the iron is known as *gray iron*. When the combined carbon is in excess, the fracture is either mottled or white, and is known as either mottled or *white iron*.

Cast iron is almost universally used for forms that must be shaped by casting, especially where weight is not objectionable, or where considerable weight is desired. It should not, however, be used for parts which are subject to shock or strain, as it is weak in tension and brittle. Cast iron makes a good bearing surface and is cheap. Surfaces of cast iron parts which are subject to continuous wear will last much longer if they are chilled.

CAST-IRON CHARACTERISTICS. Cast iron may generally be assumed to have an ultimate tensile strength of 15,000 pounds per square inch, an ultimate compressive strength of 80,000 pounds per square inch, an ultimate

shearing strength of 18,000 pounds per square inch, and a modulus of elasticity of 12,000,000. Cast iron retains its strength of 100 per cent up to 400 degrees F., but falls from this point to 92 per cent at 750 degrees F. and 42 per cent at 1100 degrees F. The strength begins to decrease at about 500 degrees F. The specific gravity of cast iron is about 7.2, the weight per cubic inch being 0.26 pound. Cast iron melts at about 2300 degrees F. Its linear expansion per unit length, due to heat, per degree F. is 0.00000556. Cast iron is probably the most complex, variable, and uncertain form in which iron is used. Not only is the amount of extraneous metals and metalloids variable, but the condition in which the associated carbon exists, and the character of this association, are determined largely by the influence of silicon and possibly other metalloids. Again, the physical properties of the metal are influenced by the casting temperature, rate of cooling, etc., so that the probable strength and stiffness of a casting can be estimated only in a general way.

CAST-IRON CUTTING WITH TORCH. In cutting cast iron by the use of the oxy-acetylene torch, special tips are used owing to the great heat and the large amount of oxygen required. The ease of cutting seems to depend largely on the physical character of the cast iron, very soft cast iron being more difficult to cut than harder varieties. The cost is much higher than for cutting the same thickness of steel, because of the larger pre-heating flame necessary and the greater oxygen consumption. In spite of this, however, this method is economical in many cases. The slag from a cast-iron cut contains considerable melted cast iron, while in the case of steel, the slag is practically free from particles of the metal. This indicates that cast-iron cutting is partly a melting operation. Increased speed and decreased cost can often be obtained by feeding a steel rod, about $\frac{1}{4}$ inch in diameter, into the top of the cut, just beneath the torch tip. This furnishes a large amount of slag which flows over the face of the cut and increases the temperature of the cast iron, thereby accelerating the melting.

CAST-IRON CYLINDERS. As a general rule, cast iron should not be used for cylinders subjected to internal pressures greater than 2000 pounds per square inch, especially if the metal is subjected (in addition to the internal pressure) to bending and tensile stresses due to external forces, because the factor of safety then becomes too low, and the thickness of the cylinder walls would have to be too great. Even when an extra good quality of cast iron is used, a pressure of 2000 pounds per square inch is close to the safe limit, because it is not possible, in most cases, to determine the maximum pressure which may be due to shocks, etc. Even if the pressure due to shocks comes within a reasonable limit, cast iron will not last long under repeated shocks. As a general rule, low internal pressures may be assumed

to be 200 pounds per square inch or less. For such pressures the general practice is to make the thickness of the metal equal to the internal diameter in inches times the pressure in pounds per square inch, and this product divided by twice the allowable working stress of the material. To this is added a variable quantity to allow for unsound castings and possible unknown stresses.

CAST-IRON GROWTH. The "growth" of cast iron is a peculiarity of certain kinds of cast iron to increase in size after repeated heatings. Cast-iron annealing ovens, 8 feet in length, which are kept red hot for prolonged periods between which they are permitted to cool off, sometimes grow to 9 feet in length in the course of their use. Cast-iron furnace grates, range fittings, etc., subjected to alternate heating and cooling are also frequently distorted and sometimes broken from the same cause. To avoid "growth" as much as possible, white cast iron should be used, which has a carbon content of about 3 per cent, and which is as free from silicon and other impurities as possible.

In a series of experiments by A. E. Outerbridge, Jr., for determining the growth of cast iron and its causes, a cast-iron bar of 1 by 1-inch section, $14\frac{13}{16}$ inches in length, was heated 27 times to about 1470 degrees F. for one hour. During this treatment it increased in size to $16\frac{1}{2}$ inches length and $1\frac{1}{8}$ by $1\frac{1}{8}$-inch cross-section. This corresponds to an expansion of nearly 41 per cent. The enlarged bar had the same weight as the bar before the treatment. Twelve additional heatings increased the dimensions of the bar until the total expansion was 46 per cent.

CAST IRON, NICHROME IN. See under Nichrome.

CAST-IRON PIPE. See Pipe.

CAST-IRON WEARING PROPERTIES. Many castings, such as engine cylinder blocks, machine slides and ways, etc., require machinability combined with resistance to wear. The chemical composition by itself is misleading as an indication of wearing properties and machinability. For example, irons containing a large amount of free ferrite have been found to wear rapidly, whereas others having considerable pearlite or sorbite in their structure have good wearing properties. Remarkable resistance to wear is developed by a chilled white iron that contains large masses of iron carbide; but this material is, of course, practically unmachinable and is applicable only in special cases. Because the main constituent of this hard iron is free cementite, the conclusion must not be drawn that its presence is desirable in readily machinable cast irons that are subject to wear. The effect of free carbide on the machinability and the wearing properties of an iron must be carefully considered.

Wearing Property of White Cast Iron. — The wearing property of white iron is due to the presence of sufficient carbides to provide an almost continuous hard bearing-surface. When the carbide spots that are present constitute only a small percentage of the total area, a different condition exists, namely, that of a few spots of hard material embedded in a softer material. A number of studies on the worn surfaces of iron containing free-carbide or phospho-carbide spots have shown that the softer material wears away, leaving the hard spots standing out in relief on the surface — a condition that would result in rapid wear of the opposing material. Besides being hard, the material in these spots is also brittle and is easily broken loose; it then becomes an abrasive between the two rubbing surfaces and results in scoring-marks. From this the conclusion can be drawn that the smallest possible amount of excess phosphide and carbide content is desirable, not only to make the iron easily machinable but to assure good wearing properties.

To Obtain Wear and Machinability. — Considering the characteristics of the various constituents, a good-wearing iron but one that is machinable has the following characteristics: (1) The presence of well-distributed primary graphite; (2) A sufficient quantity of combined carbon to make the matrix largely pearlitic or, better still, sorbitic in structure; (3) The absence of free carbide and phosphide particles.

To produce a sorbitic structure on a wearing surface, and ready machinability in other parts, various expedients have been used in the foundry. Probably the greatest progress has been made by the proper addition of nickel and chromium to cast iron. The effect of adding nickel in increasing quantities to cast iron is unique. Its addition will prevent or eliminate free-carbide spots, or white iron, while at the same time it will increase the hardness of the gray portion of the iron due to the formation of sorbite instead of pearlite. The addition of chromium in increasing quantities tends to increase the amount of combined carbon in the finished casting and, if the chromium is used in excess, it will produce areas of free carbide. By using both constituents together in the proper proportions, both elements are made much more effective.

Amounts of Nickel and Chromium. — The hardness of a casting originally free from carbide spots may be increased greatly by adding nickel and chromium in the ratio of about 3 parts of nickel to 1 of chromium. The action is somewhat as follows: The chromium increases the normal amount of combined carbon; the nickel prevents the formation of excess-carbide spots, and the nickel and chromium together tend to change the structure of the combined carbon from pearlite to sorbite and, if used in sufficient quantities, to martensite. By changing the ratio, various conditions may be met. If

a casting has corners and edges that tend to chill, nickel should be used alone to increase the hardness of the wearing surface; or a higher ratio of nickel to chromium, such as 5 parts of nickel to 1 part of chromium, may be used. In irons that show an excessive amount of free ferrite, as often occurs in slowly cooled castings, a lower ratio of nickel to chromium, such as 2 parts of nickel to 1 part of chromium, might be used safely. Observation of the life of a great variety of cast-iron parts shows that, when increased hardness is secured with freedom from free carbides, the wearing properties of an iron improve as the hardness increases; also, that an iron containing appreciable amounts of nickel takes a higher luster when polished than does a plain iron — a fact that undoubtedly aids in its resistance to wear.

CAST STEEL. The term " cast steel " is sometimes used to designate what is known as tool steel or crucible steel, but this usage is becoming more and more obsolete and should be discontinued, as it is confusing. Steel castings made by pouring molten steel into suitable molds are sometimes referred to as cast steel, but the latter term should not be applied to the high-carbon steel which is made by the crucible or electric processes and is suitable for cutting tools.

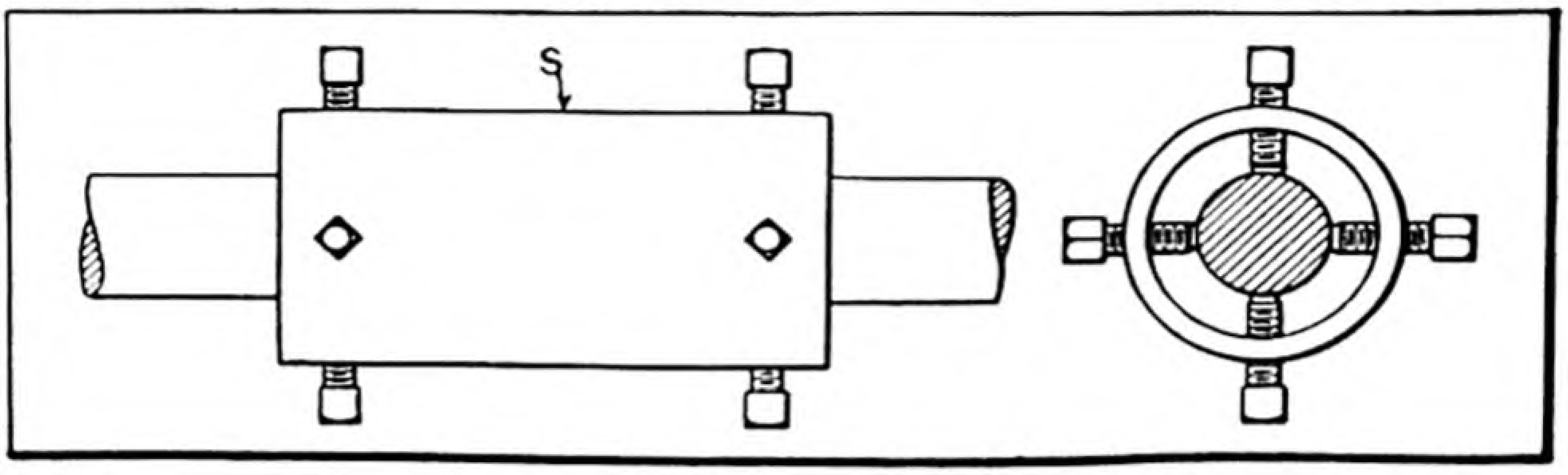
CAST WELDING. A process for welding together parts, usually of metals with a comparatively low melting point, by preparing a mold around the parts to be joined and pouring molten metal between them.

CATALYTIC AGENT. A substance present in a chemical reaction which does not take a direct part in the reaction, but which remains the same throughout, or is only temporarily affected; this agent may accelerate or retard the rate at which the reaction takes place.

CATENARY CURVE. The *catenary* is the curve assumed by a string or chain of uniform weight hanging freely between two supports. The cables of a suspension bridge, if uniformly loaded, assume the form of the catenary curve. It has, therefore, considerable importance in structural engineering. The term " catenary " is also used to indicate a certain method of carrying trolley wires. Such a system consists of one or more messenger or supporting wires stretched over the center of the tracks. Every few feet along the messenger wire are pendant hangers that clamp onto the trolley wire and retain it in a rigid, straight and horizontal line — an especially desirable feature for the operation of electric cars at high speed.

CAT-HEAD. A device used in a lathe when it is required to apply a steadyrest to a surface that does not run true and which is not to be turned. This is simply a sleeve *S* (see illustration) which is placed over the untrue surface to serve as a bearing for the steadyrest. The sleeve is made to run

true by adjusting the four set-screws at each end, and the jaws of the steady-rest are set against it, thus supporting the work.



Cat-head which is sometimes used as Steadyrest Bearing

CATHODE. The *electrodes* by means of which the current enters and leaves an electrolytic bath are known as *anode* and *cathode*, respectively. The anode is, therefore, the electrode connected with the positive terminal of the current generator, and the cathode, the electrode connected with the negative terminal.

CATTY. A modern Chinese measure of weight legalized in 1908, equal to 596.8 grams or 21.05 ounces avoirdupois.

CELLULOID. Celluloid is a dried solution of guncotton (pyrrolin) and oil. It may be machined or molded into any form by softening it in boiling water. It is highly combustible, but is only slightly affected by moisture. Celluloid is an excellent electrical insulating material, although its insulation qualities are greatly reduced at high temperatures. Clear samples of celluloid, 0.010 inch thick, at a temperature of 68 degrees F., have a puncturing voltage of from 12,000 to 28,000 volts per millimeter (0.0394 inch). If the temperature is raised to 212 degrees F., the puncturing voltage will be only one-third of that at 68 degrees F. Colored samples show from 20 to 30 per cent less *dielectric strength*, this expression being commonly used to indicate the insulating quality of a material.

CELLULOID BONDING PROCESS. Grinding wheels made by the celluloid process have a bond of celluloid, as the name implies. The abrasive grains are mixed with celluloid and this mixture is rolled into sheets from which the wheels are cut. After seasoning for several months, the wheels are ready to finish.

CELSIUS THERMOMETER. See Centigrade Thermometer.

CEMENT. The cements generally used in engineering construction are of three kinds, Portland, natural, and Pozzuolanic (slag) cements. The most reliable of these is the Portland cement, and this kind should always be used

in reinforced concrete construction. This cement consists of chemical compounds of lime and silica and lime and alumina which, when combined with water, form crystalline substances of great mechanical strength, which are capable of adhering firmly to such materials as stone and sand. See Portland Cement.

CEMENTATION PROCESS. The *cementation process* is an obsolete method for producing tool steel from wrought-iron bars. The iron bars were packed in air-tight retorts with powdered charcoal between the bars. The retorts were then put into a furnace called the " cementation " furnace, where they were heated to a red heat and permitted to remain at that temperature for several days. During this time the iron absorbed carbon from the charcoal up to about 1½ per cent of its own weight. The carburized bars, called *blister steel*, were then cut up into small pieces and were remelted in crucibles from which the metal was poured into molds. The billets thus formed were afterwards hammered or rolled into the required shapes. The carburizing of steel in the ordinary casehardening process is often referred to by many writers as " cementation."

CEMENT COPPER. The copper obtained by the precipitation of copper in the hydro-metallurgical or wet process, which is used for low-grade ores containing only from ¼ to 1 per cent of copper.

CEMENTITE. Cementite is a carbide of iron having the chemical formula Fe_3C. Steel which has cooled slowly from a high temperature contains ferrite, cementite and pearlite, in relative proportions which vary according to the chemical composition of the steel.

The strength of cast iron depends largely upon the proportion of cementite (combined carbon) and graphitic carbon. See also Steel Under the Microscope.

CEMENT, LEATHER. Leather cement is a composition suitable for attaching leather to leather, or leather to metal. A very good cement for leather on leather is made from equal parts of good hide glue and isinglass, softened in water for ten hours and then boiled with pure tannin until the whole mass is sticky. The surface of the leather to be cemented is roughened and the cement applied hot.

CEMENT, MICA AND STEEL. A gum and plaster-of-paris cement that has good adhesive qualities for attaching mica to steel is made by dissolving 1½ ounces of gum acacia in a half pint of boiling water and adding sufficient plaster-of-paris to form a paste. The materials to which the cement is applied should be pressed together as tightly as possible, in order to squeeze out the air bubbles.

Litharge, lead, and varnish form a good adhesive by mixing two parts of

litharge and one part of white lead, and working them into a pasty condition by using three parts of boiled linseed oil and one part of copal varnish. See also Glue for Mica and Steel.

CEMENTS FOR JOINTS. A strong cement which is oil-proof, water-proof, and acid-proof, consists of a stiff paste of glycerin and litharge. These form a chemical combination which sets in a few minutes. If a little water is added, it sets more slowly, which is often an advantage. This cement is mixed when required for use.

Mixture for Threaded Pipe Joints. — A good material to apply to pipe threads before making up the joints, in order to obtain a tight joint that will resist the action of gases or liquids, is made of red lead mixed with pure boiled linseed oil. This mixture has been widely used and is very satisfactory. It should have a heavy fluid-like consistency, and if applied to a clean, well-cut thread will give an excellent joint.

Shellac for Pipe Connections. — Shellac has proved to be a very satisfactory substitute for lead in sealing air and gas pipe connections. It is applied with a brush to the joints and hardens very rapidly, and being brittle, the pipes can be readily disconnected.

Graphite, Litharge, Chalk Cement. — A good cement for use in making steam pipe joints is made in the following manner: Grind and wash in clean cold water 15 parts of chalk and 50 parts of graphite; mix the two together thoroughly and allow to dry. When dry regrind to a fine powder, to which add 20 parts of ground litharge and mix to a stiff paste with 15 parts of boiled linseed oil. The preparation may be set aside for future use, as it will remain plastic for a long time, if placed in a cool place. It is applied to the joint packing as any ordinary cement.

Sulphur, Graphite, Lime Cement. — To make cement for steam, air and gas pipes, mix thoroughly powdered graphite, 6 parts; slaked lime, 3 parts; sulphur, 8 parts, and boiled oil, 7 parts. The materials must be thoroughly mixed by protracted kneading until perfectly smooth and free from lumps.

White and Red Lead Mixture. — Mix in ordinary white lead, enough powdered red lead to make a paste the consistency of putty. Spread this mixture on the joint, and when it hardens, the joint will be water tight. This mixture was used on standpipe flanges after testing all kinds of rubber gaskets without success. The mixture hardened and made a tight joint, never leaking afterward.

Steam-tight Joints. — Use white lead ground in oil and add to it as much black oxide of manganese as possible and a small portion of litharge. Knead with the hand, dusting the board with red lead. The mass is made into a small roll and screwed or pressed into position, the joint being first slightly oiled with linseed oil.

Cement for Steam and Water Pipes. — A good cement for joints on steam or water pipes is made as follows: 10 pounds fine yellow ochre; 4 pounds ground litharge; 4 pounds paris white (whiting), and ½ pound of hemp cut up fine. Mix together thoroughly with linseed oil, to about the consistency of putty.

Mixture for Rust Joint. — Mix 10 parts of iron filings, 3 parts chloride of lime with enough water to make a paste. Apply this mixture to the joint, bolt firmly together and in twelve hours it will set.

Permanent Cement for Steam Pipes. — To make a permanent cement used for stopping leaks in steam pipes where calking or plugging is impossible, mix black oxide of manganese and raw linseed oil, using enough oil with the manganese to bring it to a thick paste; apply to the pipe or joint at leak. It is best to remove pressure from the pipe and keep it sufficiently warm to absorb the oil from the manganese. In twenty-four hours the cement will be very hard.

High-pressure Water Pipes. — A highly recommended packing and cement, combined, for making tight joints in high-pressure water pipes, is made as follows: Mix with boiled linseed oil, to the consistency of putty, these ingredients: Ground litharge, 10 pounds; plaster-of-paris, 4 pounds; yellow ochre, ½ pound; red lead, 2 pounds; cut hemp fiber, ½ ounce. The hemp fiber should be cut in lengths of about ½ inch, and thoroughly mixed into the putty material. Its office is to give consistency to the cement. The cement is applied to the joint similarly to any other cement. It dries thoroughly in from 10 to 12 hours.

Cement to Resist Acids. — A cement that withstands hydrochloric acid vapors consists of rosin, 1 part; sulphur, 1 part; fireclay, 2 parts. A cement composed of boiled linseed oil and fireclay acts well with most acid vapors. A composition of glycerin and litharge is useful in this connection, especially when made up according to the following formula: Litharge, 80 pounds; red lead, 8 pounds; "flock" asbestos, 10 pounds. It should be fed into a mixer, a little at a time, with small quantities of boiled oil (about six quarts of oil being used). Sockets in 3-inch pipes carrying nitric acid, calked with this preparation, showed no leaks in nine months.

Packing to Resist Gasoline Vapor. — To prepare packing for joints in pipes, etc., carrying gasoline vapor, mix a quantity of graphite and kerosene to a thick paste and apply the paste to both sides of sheet asbestos. When dry, the packing may be cut to the shape desired. The graphite helps the asbestos to make intimate contact with the iron and thus maintain a tight joint continuously at high temperature for an indefinite time.

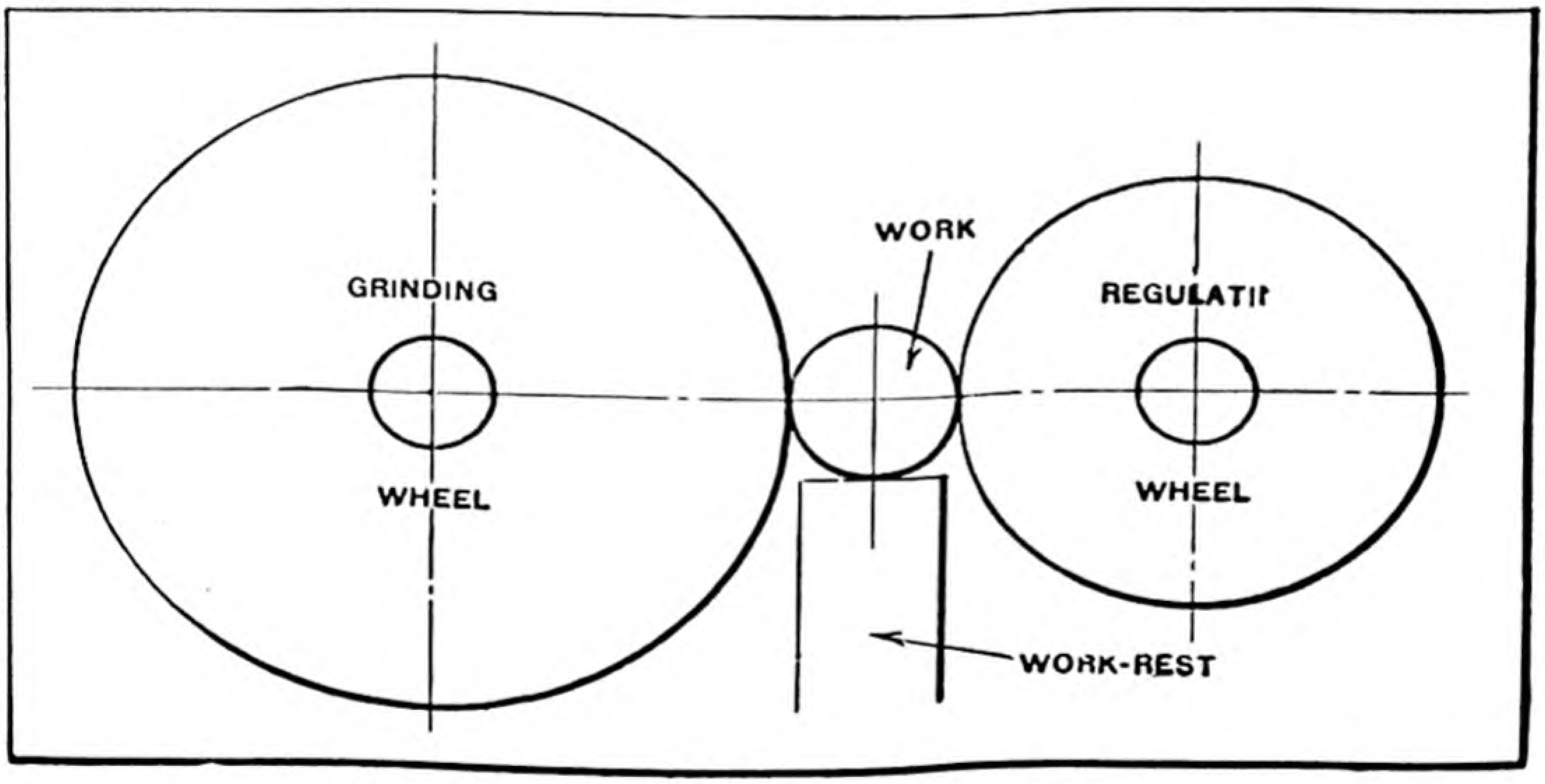
CENTER INDICATOR. The center test indicator is used for setting a center-punch mark (the position of which corresponds with the center

or axis of the hole to be bored) in alignment with the axis of a lathe spindle.

CENTERING MACHINES. Many shops have a special machine for forming centers in the ends of parts preparatory to turning the parts in a lathe. One type of centering machine is equipped with two centering heads so that both ends may be centered without reversing the position of the work.

CENTERING MECHANISMS. Centering mechanisms, in machine design, are devices used for automatically returning a machine member to the starting point or central position.

CENTERLESS GRINDING. Centerless grinding is the grinding of cylindrical work without supporting it on centers in the usual way. The principle of centerless grinding is illustrated by the diagram. Two abrasive wheels are mounted so that their peripheries face each other, one of the wheels having its axis so arranged that it can be swung out of parallel with



Principle of the Centerless Grinding Process

the axis of the other wheel by varying amounts, as required. Between these two abrasive wheels is a rest which supports the work. The two wheels are run at different speeds, the fast-running or grinding wheel at regular grinding speed, say, 5500 to 6000 feet per minute at the periphery, and the slow-running or regulating wheel at the work speed only, which latter varies according to the material, length, diameter, etc., of the work being ground. The wheels are revolved so that their adjacent faces move in opposite directions; therefore a piece of cylindrical work placed on the rest between the wheels and touching both of them will be revolved by contact with their two

surfaces. The wheels are revolved at different peripheral speeds because, if both ran at one speed, the work placed between them would be merely revolved as an idler gear, with no grinding action. The difference in surface speed of the two wheels imparts the necessary relative motion for grinding.

The success of centerless grinding lies fundamentally in the fact that the friction of rest is greater than that of motion. For this reason, the work between the two wheels will take the same peripheral speed as the slower-running, or regulating, wheel, as if geared to it.

Shoulder Grinding. — The centerless grinder may be employed for two distinct classes of cylindrical grinding. By setting the axis of the regulating wheel parallel to that of the grinding wheel and feeding the regulating wheel straight in toward the grinding wheel, the work may be ground without lengthwise travel. This affords wide application of centerless grinding to all sorts of shouldered work, such as push rods, valve stems, shackle bolts, etc., having two or more diameters, and is known as "straight-in grinding."

Through Grinding. — By setting the axis of the regulating wheel at an angle to the axis of the grinding wheel, the work is kept in constant lengthwise motion through the machine, this being known as "through grinding," and is suitable for grinding plain cylindrical parts such as piston-pins, rods, rollers for roller bearings, king bolts, etc. In this latter case there is no forward movement of the regulating wheel, except as it must be advanced by the operator from time to time to compensate for wheel wear, or its distance from the grinding wheel changed to suit different sizes of work.

Feed Wheel Beneath Work. — Another design of machine differs from the one previously referred to in that the feed wheel is directly beneath the grinding wheel so that the work being ground rests on it and is rotated by it. This feed wheel is double the width of the grinding wheel, so that the work is rotating at the proper speed when it comes in contact with the grinding wheel. The feed wheel is mounted on a vertical column, about which it may be pivoted to vary the angle with the grinding wheel any amount up to 10 degrees, thus changing the speed of the work as it passes through the machine.

CENTER OF BUOYANCY. The center of gravity of the liquid displaced by a body immersed in it. See Buoyancy.

CENTER OF GRAVITY. Under the influence of gravity, all bodies tend to move toward the earth's center. Gravity acts at every point of a body. All bodies are composed of particles, each of which has weight, and, consequently, each is attracted by gravity. A body, therefore, is really drawn downward by a large number of forces of gravity — as many as there are molecules in the body. Gravity acts in the direction of lines converging or

meeting at the center of the earth, a point so far distant, compared with the dimensions of any bodies that are likely to be considered, that these lines of action are always assumed to be parallel. It is always assumed, however, that gravity acts as a *single force* at a point called the *center of gravity.* Into whatever position a body may be placed, there is always one invariable point through which the resultant of the attracting forces always passes. This point is the center of gravity. It is a point at which, if a single force of gravity were to act in place of all the other forces, and equal in intensity to their sum, the effect upon the body would be the same as before.

CENTER OF OSCILLATION. If a body oscillates about a horizontal axis which does not pass through its center of gravity, there will be a point on the line drawn from the center of gravity perpendicular to the axis, the motion of which will be the same as if the whole mass were concentrated at that point. This point is called the *center of oscillation.* The distance between the center of oscillation and the point of suspension is called the *radius of oscillation.*

CENTER OF PERCUSSION. If a body oscillates about an axis, then the point at which, if a blow is struck by the body, the percussive action is the same as if the whole mass of the body were concentrated at that point, is called the *center of percussion.* This point is located at the same point as the center of oscillation.

CENTER REAMERS. A "center reamer" is a reamer the teeth of which meet in a point. By their use small conical holes may be reamed in the ends of parts to be machined as on lathe centers. When large holes — usually cored — must be center-reamed, a large reamer is ordinarily used in which the teeth do not meet in a point, the reamer forming the frustum of a cone. Center reamers for such work are called "bull" or "pipe" center reamers.

CENTERS, MACHINE TOOL. The centers of a machine tool, such as a lathe or grinding machine, are the conical points between which the part to be turned or ground is held. The work revolves upon the stationary or *dead center* of the tailstock and revolves with the *live center* in the headstock spindle.

Experiments have shown that on lathe work at both high and low speeds the life of high-speed steel centers is easily ten times that of carbon-steel centers. In cases where the work is long and of fairly small diameter, when carbon centers are likely to burn off due to the expansion of the work being machined, the danger of spoiled centers and spoiled work seems to be entirely overcome by the use of high-speed steel centers. In grinding machines, high-speed centers also seem to stand the wear of the abrasive which gets into

the cutting compound and which deteriorates the carbon-steel centers very rapidly. One of the problems in substituting high-speed steel centers for carbon centers is the increased cost due to the higher priced material. But by using a chrome-nickel steel shank and a high-speed steel point an equally satisfactory center can be made at a much lower cost.

CENTIGRADE THERMOMETER This thermometer, also known as the Celsius, was originated by the Swedish astronomer Celsius, who, in 1742, described a thermometer provided with 100 graduations between the freezing and boiling point of water. On the Centigrade thermometer scale, the zero point is placed at the freezing point of water, and the graduation "100" coincides with the boiling point of water; hence, the zero on the Centigrade scale corresponds to the 32-degree graduation on the ordinary Fahrenheit thermometer, and the 100-degree graduation on the Centigrade scale corresponds to the 212-degree graduation on the Fahrenheit scale.

$$\text{Degrees Fahrenheit} = \frac{9 \times \text{degrees C.}}{5} + 32$$

CENTIMETER-GRAM-SECOND MEASUREMENT SYSTEM. See Absolute System of Measurement.

CENTRIFUGAL BABBITTING MACHINE. Babbitt can be cast in parts by means of a machine of the centrifugal type. This machine contains a rotating spindle which can be quickly started and stopped. On the front end of this spindle there is mounted an aluminum faceplate which carries a work-holding fixture. This fixture consists of two hardened, ground and polished steel plates, one of which is fastened to the faceplate, while the second is mounted on three spring plungers that allow it to be moved outward for loading the work. The work is clamped to the inner plate by the three springs, this action also locating the piece in one direction. When a connecting-rod is being babbitted, it is located in the other direction by a pin that fits the wrist-pin hole.

The piece to be babbitted is first cleaned and tinned and placed in the fixture before being allowed to cool. The spindle, faceplate, fixture and work are then rotated together, after which a measured quantity of molten babbitt is poured into the hole in the center of the outer fixture plate. As the babbitt cools, the centrifugal force throws it against the proper surface of the work, where it solidifies. This method of depositing babbitt in bearings obviates blow-holes and brings all impurities to the surface of the babbitt, from which they are removed in the first boring operation. In babbitting a connecting-rod having a $2\frac{1}{8}$-inch bore, $1\frac{9}{16}$ inches long, a production of 75 rods has been obtained per hour.

CENTRIGUFAL BLOWER. A blower operating on the same principle as the ordinary ventilating fan, but designed for maintaining pressures from 3 to 4 pounds per square inch and used for cupola furnaces and similar requirements.

CENTRIFUGAL CASTING. The centrifugal casting of metals is an old art, but it did not assume commercial importance until recent years. This process has already become an important factor in such work as the manufacture of paper-mill rolls, railroad car wheels, and cast-iron pipe. The centrifugal casting process has been successfully applied in the production of non-metallic tubes, such as concrete pipe, in the production of solid castings by locating the molds around the rim of a spinning wheel, and also to a limited extent in the production of solid ingots by a largely similar process. The usual way of casting hollow objects such as cast-iron pipe, is by introducing molten metal into a spinning mold. Where the chilling of the metal is extremely rapid, as, for example, in casting cast-iron pipe against a water-cooled chilled mold, it is imperative to use a movable spout, the latter sliding at a certain predetermined rate so that by the time the nozzle discharging the metal comes out of the mold the entire pipe is completed. The particular feature that determines the field of application of hot-mold centrifugal casting is the ability to produce long cast shapes of comparatively thin metal.

CENTRIFUGAL COMPRESSOR. A blower used for pressures from 6 to 120 pounds per square inch or more; same as *turbo compressor*.

CENTRIFUGAL DRYERS. See Dryers, Centrifugal.

CENTRIFUGAL FEED-PUMPS. The centrifugal boiler feed-pump has come into extensive use, because it has many characteristics superior to the well-known plunger pump. There are, nevertheless, many operators who still prefer the plunger pump, providing it is large enough to run at slow speed. A plunger pump should preferably not be operated faster than 30 strokes a minute, nor with a piston speed of over 60 feet a minute. Some of the advantages of the centrifugal boiler feed-pump are as follows: Steady pressure on entire feed system; no regulators necessary, because pressure seldom increases over 15 or 20 per cent at no output; lower maintenance cost; less floor space; and lower steam consumption. One disadvantage is the possibility of excessive heating of the pump casing when operated at full speed and practically no output. Some operators prefer pump governors, but because of the long periods of inactivity the ordinary pump governor frequently does not work when required. The high suction head needed when pumping warm water and the possibility of reduced output, due to erosion of the wearing rings, are other disadvantages.

CENTRIFUGAL FORCE. If a body, as, for example, a weight fastened to a string, is revolved in a curved path, a pull is exerted on the string, which increases with the velocity with which the body is revolved. According to the laws of motion, a body tends to move in a straight line unless it is acted upon by some external force which causes it to change its direction; hence, a body revolving as mentioned would tend to move in a line tangential to the circle in which it revolves, if it were not restrained from doing so by the string. The force exerted by the body upon the string or cord which restrains it is called the *centrifugal force*. Whenever any body revolves about a center it exerts a centrifugal force upon the arm or cord which restrains it from moving in a straight (tangential) line. The centrifugal force increases rapidly with the velocity, the increase being in proportion to the square of the velocity, so that, if the velocity is doubled, the centrifugal force becomes four times as great; if the velocity is made three times as great, the centrifugal force becomes nine times as great, etc. The centrifugal force also increases directly with the weight of the revolving body, but decreases with an increasing radius.

CENTRIFUGAL PUMPS. A centrifugal pump in its simplest form consists of an outer casing in which inlet and outlet passages are formed and which encloses a revolving impeller, rotor, fan, bucket or runner, various names being applied to this part. The impeller has blades which are usually curved backward with reference to the direction of rotation. When the pump is in operation, the water is drawn in through the center or "eye" of the impeller, and as the water is whirled around by the blades, it is thrown outward as the result of centrifugal force and passes through the discharge outlet. The early designs of centrifugal pumps were only adapted to low pressures, and were used for forcing large quantities of water to small heights, in connection with the drainage and irrigation of land, emptying locks, and similar classes of work for which a reciprocating piston pump of sufficient capacity would have been too large and expensive. The modern centrifugal pump has been developed until the various types and designs now available are adapted to various classes of service and for high heads or pressures.

Advantages of Centrifugal Type. — The principal advantages of centrifugal pumps, as compared with the reciprocating type, are greater compactness, lower initial cost, adaptability to a greater variety of conditions, little attention while operating, simplicity of construction, and reliability. The centrifugal pump has another decided advantage in that it can be directly connected to a steam or gas engine, steam turbine, or electric motor. These pumps deliver water continuously, so that shocks in the pipe lines are avoided, and they operate with little or no vibration, which makes it un-

necessary to install a heavy foundation. If the impeller blades are carefully designed, it is possible to close a valve at the end of the discharge line without an increase in pressure, so that the pump is capable of operating under practically all conditions, without danger of breakage.

Classes of Centrifugal Pumps. — There are two principal classes of centrifugal pumps, namely, the *single-stage* pump and the *multi-stage* pump. The single-stage type of pump has a single impeller. The head of water which single-stage pumps of commercial design are capable of developing does not vary widely from the result obtained by the formula:

$$\text{Head} = \frac{V^2}{2\,g},$$

in which V = peripheral velocity of the impeller in feet per second; and g = acceleration of gravity, or 32.16 feet per second.

By arranging a number of centrifugal pumps in series so that the discharge of one is led to the suction of the succeeding pump, the head developed may be multiplied to any desired extent. Some of the early designs of multi-stage pumps were practically a series of single-stage pumps arranged in series, with but little modification of the construction. The modern designs, instead of having individual housings or casings for each pump, are equipped with one common housing with passages so arranged that the water flows from the discharge of one pump to the inlet of the next pump, through channels or passageways designed to reduce the losses through friction and eddy-currents as much as possible.

CERIUM. Cerium is one of the metallic chemical elements; its chemical symbol is Ce, and its atomic weight, 140.25. The metal has some similarity to iron in its appearance. The industrial importance of cerium is due to the use of its dioxide in the making of incandescent gas mantels. This dioxide is a white or pale yellow compound which, when heated to a high temperature, will give out a white brilliant light.

CHAIN. A surveyor's length measure; 1 chain = 4 rods = 22 yards = 66 feet = 100 links = 20.117 meters.

CHAIN ANNEALING. The annealing of chains before they are first used is good practice, as in that way any internal stresses that may have been set up in the process of manufacture are thereby relieved. Annealing a fatigued or crystallized chain may improve its ductility without restoring its original physical properties. In every case, however, the annealing should be carefully performed under proper conditions as to determination and control of the temperature, and with a full knowledge of the chemical composition of the material under treatment.

CHAIN, ENGINEER'S. See Engineer's Chain.

CHAIN-HARDENING FURNACE. A special furnace in which the chain to be heat-treated passes over two sprockets, one at the entering and one at the leaving end of the furnace. After the chain has passed through the heating chamber, it enters directly into a cooling bath (without passing through the outer air) and then passes over the leaving sprocket and is wound upon a reel.

CHAIN-MAKING MACHINE. A machine employed for the making of chain of either the weldless or welded type. Some of these machines are merely wire- or rod-bending machines that bend the links to the required size, while others, generally of the electric type, include an arrangement for welding.

CHAIN MATERIALS. The best material for crane and hoisting chains is a good grade of wrought iron, in which the percentage of phosphorus, sulphur, silicon, and other impurities is comparatively low. The tensile strength of the best grades of wrought iron does not exceed 46,000 pounds per square inch, whereas mild steel with about 0.15 per cent carbon has a tensile strength nearly double this amount. The ductility and toughness of wrought iron, however, is greater than that of ordinary commercial steel, and for this reason it is preferable for chains subjected to heavy intermittent strains, because wrought iron will always give warning by bending or stretching, before breaking. Another important reason for using wrought iron in preference to steel is that a perfect weld can be effected more easily.

Heavy welded chains of either mild steel or wrought iron have been supplanted in many cases by cast-steel chain. Mild-steel chain has been found to be either too ductile to retain its form under severe stress or too hard to insure reliable welds when the links have been welded together. Cast-steel chains are made successfully and practically either by casting the whole chain integral, or by pouring the metal into separate link molds and then setting these links in alternate molds and pouring the intervening links around those first cast. Chains of almost any size can be, and have been, successfully cast, either integral or by alternate molds. The steel used is a special alloy electric steel; it is stated that electric steel is the only grade of steel that can be used successfully and even this steel must be specially heat-treated. The steel casting chains are very strong and of excellent durability. It is essential that steel casting chains be carefully annealed.

CHAIN NOMENCLATURE, ROLLER. See Roller Chain Nomenclature.

CHAIN OILING. A method used for lubricating horizontal journals running at high speed, in which an endless loop of chain, resting on and

moving with the shaft, dips into an oil reservoir at the lower side and brings up the oil to the top surface of the journal, from where it flows over into the oil grooves.

CHAIN SLINGS. See Slings.

CHAIN SPEEDS, ROLLER. See Roller Chain Speeds.

CHAIN SPROCKET DESIGN. See Sprocket.

CHAIN STRENGTH. The ultimate, or breaking, strength of a chain is usually between 1.5 and 1.7 (average 1.66) times the ultimate strength of the straight bar or stock from which it is formed, instead of twice that amount, as might at first thought be expected because of the doubling of the bar in forming the link. The link of a chain under load is not in the simple physical condition of a bar under direct tension in a testing machine. A link is subjected to a direct tension, due to the load or pull, and to a bending moment that induces tension on the outer fibers and compression on the inner fibers of that part of the link subject to bending. The stress in tension due to bending may equal more than three (for stud links) or four (for open links) times that produced by the direct pull evenly distributed over the cross-sectional area of the bars.

Another empirical formula that is commonly used for calculating the breaking load, in pounds, of wrought-iron crane chains is: $W = 54{,}000\ D^2$, in which W = breaking load in pounds and D = diameter of bar (in inches) from which links are made. The working load for chains should not exceed one-third the value of W, and, in many cases, it should be less. When a chain is to be wound around parts such as castings, and severe bending stresses are to be introduced, a greater factor of safety should be used.

Safe Working Loads. — An investigation of these matters conducted at the Engineering Experiment Station of the University of Illinois, with a critical analysis of the results attained, affords a simple and convenient formula for ascertaining the actual maximum stresses in chains and links under specified loads due to combined pull and bending, and thus furnishes a reliable means of computing safe working loads for chains. This formula, for chains with open links of the usual form, is as follows:

$$F = 2.5 \times \frac{P}{D^2}.$$

For chains with stud links,

$$F = 2 \times \frac{P}{D^2}.$$

In these formulas, F = extreme fiber stress in tension, in pounds per square inch; D = diameter of stock, in inches; P = chain load, in pounds.

In computing the safe loads for open-link chains a value of 12,000 pounds per square inch for the allowable maximum fiber stress, and an elastic limit of 24,000 pounds per square inch may be used, thus assuring in every case an actual safety factor of at least 2, based on the elastic limit of wrought iron, or more if open-hearth, low-carbon steel is used.

CHAINS, STUDDED. Tests have demonstrated that the ultimate breaking strength of a chain with studded links is less than that of an unstudded chain. This is probably due to the fact that the open links of an unstudded chain collapse until the sides are approximately parallel, so that the stresses are lower than in the studded links, the sides of which are prevented from collapsing by the studs. The principal function of the stud is to prevent the chain from kinking and catching, so that it will run free from chain lockers, etc. The stud also prevents the chain from becoming rigid under heavy strains.

CHAIN TRANSMISSION. This term relates to the use of chains and sprockets for transmitting power. This system of power transmission provides a positive speed ratio between the driving and driven shafts, and it is especially adapted where the center distances between the shafts are too long for gearing and too short for belting. Chain drives are compact, and as there is no initial tension on the chain, journal friction is minimized. See Silent Chain Transmission; Roller Chain; Sprocket.

CHANG. A Chinese length measure, legalized in 1908. It is equal to 3.2 meters, or 10 feet 6 inches.

CHANGE-GEARS. The gears used on screw-cutting lathes for connecting the lathe spindle stud and the lead-screw are commonly known as *change-gears*. Prior to the introduction of the quick change gear mechanism on lathes, an assortment of these gears was provided with every screw-cutting lathe, different sizes being employed for cutting threads of various pitches; hence, the name "change-gears." The gears of a milling machine, used to drive a dividing or index head from the table feed screw for such work as cutting spirals or helices, are also known as change-gears, and this term is applied to various other changeable gearing.

CHANGE-GEARS FOR THREAD CUTTING. The change-gears for cutting threads of various pitches with an engine lathe, are usually shown by a table or index plate attached to the lathe, but the proper gears to be used can be calculated by the following rule.

Rule. — First find the number of threads per inch that is cut when gears of the same size are placed on the lead-screw and spindle stud, either by trial or by referring to the index plate. Then place this number as the numerator of a fraction, and the number of threads per inch to be cut, as the de-

nominator; multiply both the numerator and denominator by some trial number, until numbers are obtained which correspond to numbers of teeth in gears that are available. The product of the trial number and the numerator (or "lathe screw constant") represents the gear for the spindle stud, and the product of the trial number and the denominator, the gear for the lead-screw.

CHANNEL. The name applied to a standard structural steel shape consisting of a web and two flanges projecting at right angles to the web and on the same side, thus forming a channel or U-shaped section. See Structural Shapes.

CHANNELING. The formation of irregular sections of sheet metal of indefinite length for use in the manufacture of metal furniture, automobile rims, show cases, etc., in the small sizes, and for structural steel work, gutters, molds for cement forms, steel car manufacture, and kindred uses, in the larger sizes, by means of rolling, is known as channeling. Sheet stock of any metal may be formed cold by channeling, and any thickness up to $\frac{1}{4}$ inch may be worked without difficulty. The speed at which this class of work is handled varies from 50 to 90 feet per minute, according to the metal and the shape to be produced.

CHAPLETS. When the cores of foundry molds are not supported or held securely by suitable core-prints, and are likely to be moved from their proper position by the wash and lifting action of the molten metal, it becomes necessary to secure or anchor them with chaplets. These are made in a variety of shapes and sizes to meet the different conditions that may arise.

CHARCOAL. Charcoal is the residue consisting of impure carbon which is obtained by expelling the volatile matter from animal or vegetable substances. The most abundant source of charcoal is wood. Under average conditions, 100 parts of wood yield about 60 parts, by volume, or 25 parts, by weight, of charcoal. The modern methods of producing charcoal from wood consist in using a cast-iron retort in which the wood is heated in order to remove the volatile constituents. Valuable by-products are also obtained in this manner (wood alcohol, wood tar, etc.). The uses of charcoal in the industries are many. It is an important fuel, especially in many metallurgical processes; it is also important as a constituent of gun powder; it is used as a filtering medium; and it has the power of removing coloring matters from solutions, and is, therefore, used to some extent in laboratory practice. The actual specific gravity of wood charcoal is 1.5, but owing to its porosity it floats on the surface of water.

CHARLES' LAW. The volume of a perfect gas at constant pressure is proportional to its absolute temperature. This is known as the "law of

Charles." Let V = volume of gas at 32 degrees F., and V_1, the volume of the gas at any other temperature T_1, then:

$$V_1 = V\left(1 + \frac{T_1 - 32}{491.2}\right).$$

CHARPY TEST. The Charpy test for hardness consists of striking specially prepared specimens of work with blows that can be figured in foot-pounds. The hardness is not measured, but instead the shock-resisting qualities of the work are determined. See Impact Tests.

CHARRED BONE. A material frequently used in carburizing mixtures for increasing the carbon content of the surface of low-carbon steel, so that it may be casehardened. A mixture of 35 per cent of charred bone, 30 per cent of burnt leather, and 35 per cent of wood charcoal, by weight, is frequently used. See also Carburizers.

CHASERS. A chaser is a form of threading tool having a number of teeth instead of a single point like the threading tools commonly used in connection with lathe work. There are three general classes of chasers; namely, hand chasers, threading tool chasers (which are rigidly held in a tool-holder and used like an ordinary lathe threading tool), and die chasers, such as are used in thread-cutting dies.

Chaser Throat. — The leading side or corner of each chaser in a die-head is usually beveled. This beveled edge is known as the "throat" of the chaser and serves to begin the cut gradually when the die is first starting a thread and also as it advances. The throat of the chaser not only inclines relative to the axis of the die (or screw being cut), but it is given clearance back of the cutting edge in a circumferential direction. In some cases, the throat angle must be abrupt in order to cut a full thread close to a shoulder. Aside from a requirement of this kind, the throat should preferably be ground so that the work of cutting a thread to the full depth is distributed over at least two or three on the leading side of the die.

CHASING DIAL. The thread-chasing dial, or thread indicator, which is attached to the carriage and has a worm-wheel meshing with the lead-screw, shows when to re-engage the half-nuts of the apron with the lead-screw when cutting screw threads which are not a multiple of the number of threads per inch on the lead-screw. If the half-nuts were engaged at random for taking each successive cut the tool might not follow the original cut.

CHATTERING. The term "chattering," as applied by machinists, means the formation of slight ridges or nicks upon a part that is either being turned, planed, milled, or ground. Chattering may be caused by the design of the machine, the nature of the work or its proportions, the care

and adjustment of the parts of the machine, the methods of setting the work in the machine or of driving it, the shape of the cutting tool or the manner in which it is set in the machine, or the speeds and feeds employed for cutting.

The action that occurs when a turning operation is accompanied by chattering is as follows: Either the tool or the work is momentarily deflected, causing slight changes in the depth of cut taken. This action occurs very rapidly as the part revolves, so that the surface, instead of being turned smooth, is covered with small ridges or corrugations. Chattering not only mars the turned surface, but quickly dulls the cutting edge of the tool. High cutting speeds tend, far more than slow speeds, toward producing minute and rapid vibrations in all parts of the machine, and, in order to prevent or absorb these vibrations, the members of the machine which support the tool and work should be massive, to secure the required rigidity. A common source of chatter can be eliminated by a systematic method of adjusting the working parts of the machine in order to eliminate unnecessary play or lost motion.

The principal cause of chatter marks on parts which are ground in cylindrical grinding machines is the vibration of the work, which may be due to a number of causes, such as a lack of proper support for the work, lack of rigidity in the machine and incorrect work speed.

CHECKING OF STEEL. The cracking or checking which sometimes occurs when grinding high-speed steel tools is said to be caused invariably by the use of cooling water while rough-grinding the tool. A practice recommended is as follows: Have the tool rough-forged to approximately the required shape; grind the tool slowly at first until it becomes warmed through, after which the grinding may be done rapidly without injury to the tool, but water should not be used when rough-grinding, as it tends to cause checking.

CHECKING SYSTEMS FOR TOOLS. See Tool Checking Systems.

CHECK-NUT. A check-nut is used for binding or securing the ordinary nut screwed onto the end of a bolt. A mistake which is often made in machine design and construction is to put the check-nut on top instead of at the bottom of the regular nut. The check-nut ordinarily is made only one-half or five-eighths the thickness of the regular nut, the latter commonly having a height equal to the diameter of the bolt. The reason why the thinner check-nuts should be placed below and the thicker regular nuts on top is that the pressure on the threads of the lower nut is small compared with the pressure on the threads of the upper nut, if the nuts are tightened in such a manner that they actually bind each other in place. The upper nut must be tightened down so as to place a greater stress on the bolt than

is placed on it by the lower nut, because in order to secure a locking action the nuts must bear against opposite sides in the thread. If the upper nut is not tightened down so as to place such a stress on the bolt that the nuts bear on opposite sides of the thread, then the check-nut does not act as a check-nut at all, but merely increases the length of the nut already in place. This may have some tendency to prevent the nut from jarring loose, but it is not the condition actually sought.

"CHECK" TYPE OF GAGE. "Checks" are simply standards for the inspection of wear of working and inspection gages. They indicate when the gages are so worn by use that they are no longer suitable for the purpose for which they are intended. Checks may be used for a considerable number of gages, but are necessary in the case of many types, such, for example, as ring or snap gages which are too small to be measured by ordinary methods.

CHECK-VALVES. Check-valves are designed to allow any fluid to pass through them in one direction only, any pressure in an opposite direction tending to immediately close the valve. Check-valves are made in several forms, including the globe check-valve, the swing check-valve and the ball check-valve. The ball type is designed particularly for use with heavy liquids, such as molasses or heavy oils. The particular advantage of the ball valve is that it opens readily and gives a free and unobstructed passage through the valve body, which is not likely to become clogged or obstructed by foreign matter. The boiler check-valve is located between the injector and the boiler, its function being to permit the passage of feed water to the boiler, without permitting any backward flow when the injector is not working. It is essential that the check-valve be tight and have the proper amount of lift. See Automatic Stop and Check-valves.

CHEMICAL AFFINITY. The force which holds together the molecules of a substance. It is also known as chemical force.

CHEMICAL ANALYSIS. The resolution of complex bodies into their elements is termed *chemical analysis.* When only the constituent elements of a substance are determined, the analysis is said to be *qualitative*; but when both the constituents and the percentages of each are determined, the analysis is said to be *quantitative.* When the quantitative analysis determines the percentages of the compounds of which a substance is made up, it is said to be a "proximate analysis"; when the quantitative analysis determines the percentages of the elements of a substance, it is said to be an "ultimate analysis." For example, the proximate analysis of coal, which is the one usually made, shows the percentages of volatile matter, fixed carbon, moisture, sulphur, and ash; but the ultimate analysis will

show the percentages of hydrogen, oxygen, carbon, nitrogen, etc. An analysis performed with the aid of a liquid solvent or reagent is termed a "wet" or "humid" analysis. A *reagent* is any substance used to effect a chemical change in another substance for the purpose of determining its component parts, or to ascertain its percentage composition. An analysis performed with dry re-agents and heat is termed a "dry" analysis. The analysis of ores is usually termed "assaying"; this is divided into "wet assaying" and "fire assaying."

CHEMICAL CHANGE. A change in a substance which takes place within the molecules is called a chemical change. For example, if a magnesium rod is heated, it will combine with oxygen and form a white easily powdered substance known as "magnesia" or "magnesium oxide"; the magnesium has thus undergone a chemical change.

CHEMICAL EQUATIONS. Chemical reactions are generally stated in the form of equations. In these, the symbols and formulas of the substance and the actions that take place are shown on one side of the equals sign and the result obtained is shown on the other. The equations show the relative number of molecules and atoms involved. They also indicate the weight of the quantities involved. As in the case of algebraic equations, the quantities on one side of a chemical equation must always equal the quantities on the other. Thus if the weight of one factor or product is known, the weights of all other factors and products may be calculated from the equation representing the reaction. As an example of a chemical equation, the following is given which indicates that calcium carbide and water forms calcium hydroxide and acetylene:

$$CaC_2 + 2H_2O = Ca(OH)_2 + C_2H_2.$$

CHEMICAL EQUIVALENTS. Owing to the difficulty of determining atomic weights, some chemists have advocated the use of "chemical equivalents." The *equivalent* of an element is the relative weight of the element that combines with one part, by weight, of hydrogen. For example, 8 parts of oxygen, 35.4 parts of chlorine, 80 parts of bromine, and 16 parts of sulphur combine, respectively, with 1 part, by weight, of hydrogen; therefore, 8, 35.4, 80, and 16 are said to be the equivalents of these elements. However, many elements do not combine with hydrogen, and some combine with it in more than one proportion, so that the difficulty of determining the equivalent is as great as the difficulty of determining the atomic weight.

CHEMICAL FORMULA. An abbreviation used to designate a chemical compound; it shows how many atoms of different chemical elements

are contained in one molecule of the compound. For example, the chemical formula of ferric oxide is Fe_2O_3, which shows that one molecule of ferric oxide contains two atoms of iron, the symbol of which is Fe, and three atoms of oxygen, the symbol of which is O.

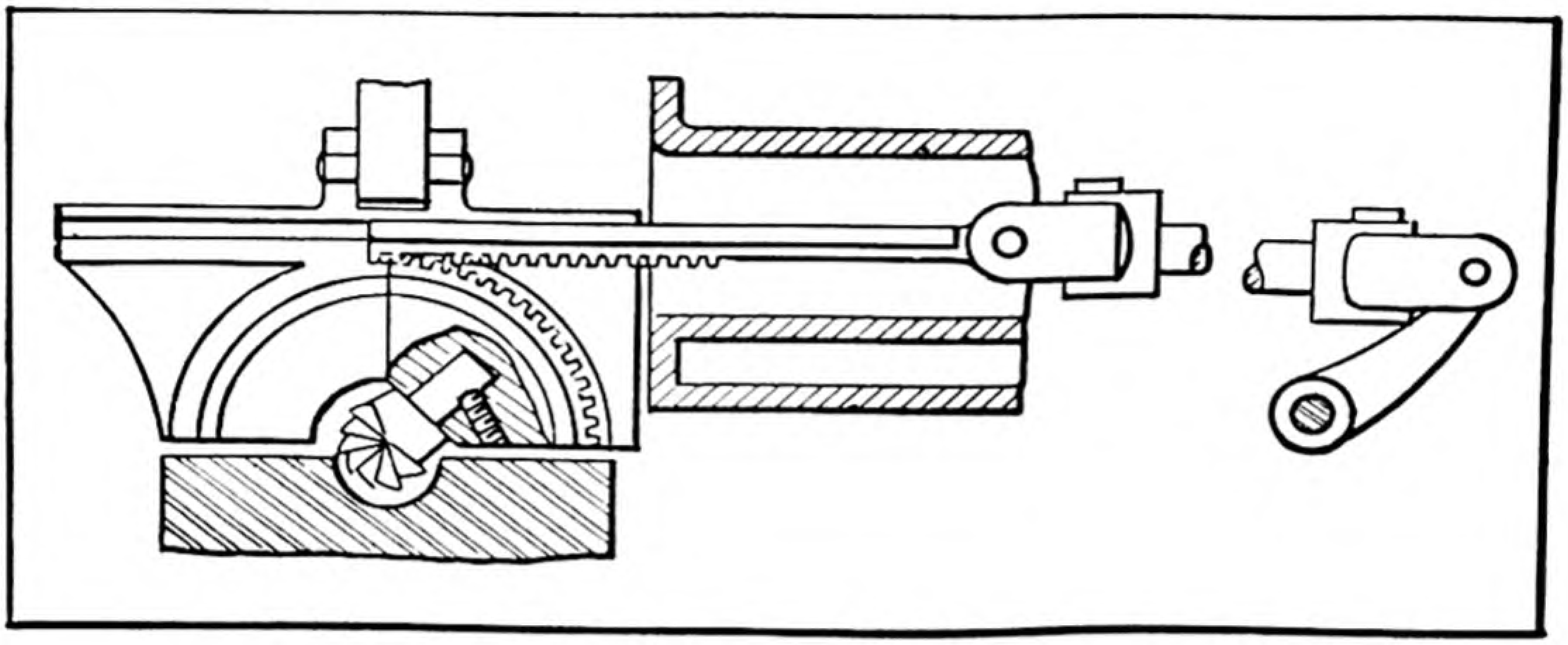
CHEMICAL REACTION. Any chemical change that takes place is termed a *chemical reaction.* The change may be a rearrangement of the atoms of the different molecules, the combining of two or more molecules into one, two, or more different molecules, or the splitting up of one molecule into two or more molecules. All molecules entering into a reaction are called "factors"; those issuing from a reaction are called "products."

CHEMISTRY. Chemistry is the science that treats of the composition of substances and the changes they undergo. Chemistry has in the past generally been divided into two classes, organic and inorganic, because of the belief that some substances could not be artificially produced; but, with modern developments in the laboratory, many of the substances classified as organic have been produced from inorganic matter. The division, however, is still maintained as a matter of convenience, and *organic chemistry* is commonly said to be the chemistry of carbon compounds, while *inorganic chemistry* is the chemistry of all other elements and compounds. This definition, however, is not absolutely true, as some carbon compounds, such as carbon monoxide, carbon dioxide, carbon disulphide, silicon carbide, and iron carbides that occur in cast iron and steel, are practically always considered as inorganic; while some substances, such as chloroform, that do not contain carbon, are treated as organic. Chemistry is also divided into *synthetic*, or the building up of more complicated from less complicated substances, and *analytic*, or the determining of the components of a substance. The term "synthetic" is also used for substances made by artificial means in the laboratory, to distinguish them from like substances obtained directly from plants or animals.

CHERRYING. The term "cherrying" relates to the milling of circular or spherical impressions in dies as for example when a milling cutter is sunk to one-half its depth in milling out a circular recess. A *cherry* is a milling cutter, usually made integral with an arbor the length of which varies with the requirements of the work to be done. This cherry may be held in the spindle of a standard milling machine.

Many devices and attachments for both the milling machine and die-sinking machine have been devised to eliminate chipping and the difficult hand work. In order to avoid hand work as much as possible in the making of drop-forging dies, etc., die-sinking machines have been equipped with

a *secondary* or *cherrying head* (see illustration), which is an integral part of the machine and is used for milling circular impressions in dies which are too deep to be cut by an ordinary cutter mounted upon an arbor.



Section of Cherrying Head

CHESTER EMERY. A natural abrasive obtained from Chester, Mass., which is not considered to be of quite as high a grade as the imported Naxos and Turkish emery. It contains a large percentage of non-cutting elements; the crystalline alumina, which determines the cutting qualities, being only about 55 per cent of the total composition.

CHESTNUT COAL. A term indicating the grading of the coal as to size. This grade will not pass a screen of $\frac{3}{4}$-inch mesh, but will pass a screen of $1\frac{3}{8}$-inch mesh.

CHEVAL-VAPEUR. Same as *Metric Horsepower*.

CH'IEN. A Chinese measure of weight, legalized in 1908, equal to 3.73 grams or 57.6 grains.

CH'IH. A Chinese length measure, legalized in 1908, equal to 320 millimeters, or 12.6 inches.

CHILLED CASTINGS. A chilled casting is one which has been cooled suddenly by casting it in contact with some material which will rapidly conduct heat away from the surface of the casting. The effect is to produce a surface of great hardness which will withstand considerable wear. Such castings are used for many purposes, such as for railroad car wheels, rolls, jaws of crushing machines, stamps, etc. In the case of cast-iron chilled castings, the chill is always produced by iron in the mold. Either the complete mold is made of iron, or iron slabs called "chills" are imbedded in the mold, so that certain surfaces (those exposed to the greatest wear)

are chilled. Thus, the tread of car wheels and the wearing surfaces of machine tool beds are often chilled to increase the life of the wheel or machine ways. A casting poured against a surface of solid iron may be chilled from $\frac{1}{8}$ inch to 1 inch in depth. When a casting has a heavy section which adjoins a comparatively light section, chills have been used, in special cases, to secure more uniform cooling between the heavy and light sections in order to prevent the formation of internal blow-holes.

Chills for Castings. — Chills may be used as part of the mold or in the same capacity as a core. The patternmaker's job is to fit the pattern to the chill as they are rammed up together; if a round hole is to be chilled, core-prints are fitted to the pattern and the chill is made with considerable taper so that it may be driven out. It is sometimes desirable to make sections of pipe to bolt together without finishing the flanges; and to do this, metal ends are used in the mold, not to chill the casting but to form a finished flange. In this case, the flanges are made long to form core-prints for the metal ends, the face sides of which are grooved with concentric V-grooves to give the packing a hold. The core is carried on an arbor that fits openings turned in the end pieces which are also drilled with holes through which the bolt hole cores are pushed.

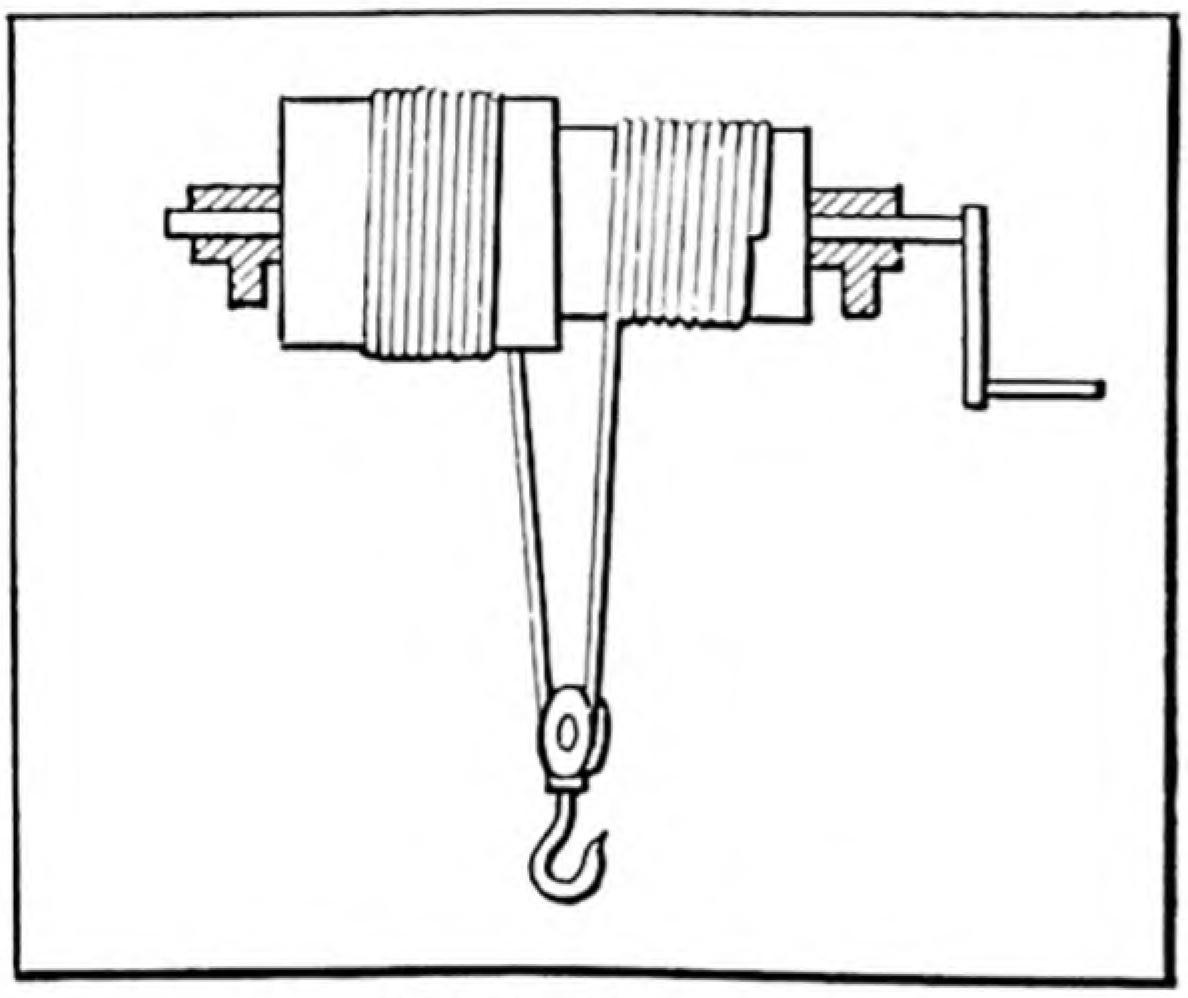
CHIMNEYS. The requirements of a chimney are that it shall provide sufficient draft to burn the required amount of fuel on the grate of a boiler in a given time, and also carry off the obnoxious gases. The strength of the draft depends upon the height of the chimney, while the volume of the gases to be carried off fixes the sectional area of the flue. The exact proportions depend upon the kind and amount of fuel to be burned, the design and arrangement of the boilers and connecting flues, and the altitude of the plant above the sea level. No universal formula has yet been devised which covers all of these conditions, so that it is more common in designing a chimney to use experimental data obtained from chimneys in actual use. As a rule, in ordinary boiler work the chimney lining need not be more than one-fifth of the height of the chimney, if the exhaust gases do not have a temperature over 800 degrees F. If the temperature of the exhaust gases is higher, the lining must extend higher inside the chimney.

The *draft* produced by a chimney is due to the comparatively high temperature of the furnace gases which pass up the chimney. As these hot gases are lighter than an equal volume of outside air, the pressure within the chimney is less than the atmospheric pressure surrounding the chimney; consequently, air from the outside naturally flows through the furnace and into the chimney and the necessary draft is thus obtained.

CHIN. A Chinese measure of weight, legalized in 1908, equal to 596.8 grams or 21.05 ounces avoirdupois.

CHINA CLAY. An aluminum silicate found in nature as a fine white powder. It is used in paints for the protection of iron and steel against corrosion. It grinds in 28 per cent of oil.

CHINESE ALLOYS. There are a number of alloys known as Chinese bronze, Chinese copper, etc. These have somewhat varying compositions. Chinese bronze, according to one formula, contains 83 per cent copper, 10 per cent lead, 5 per cent tin, and 2 per cent zinc. Chinese white copper contains about 40 per cent copper, 32 per cent nickel, 25 per cent zinc, and 3 per cent tin. The metal used for Chinese gongs contains 81 per cent copper and 19 per cent tin; this is practically the same composition as that used for bell metal, which is 80 per cent copper and 20 per cent tin.



Chinese Windlass

CHINESE WINDLASS. The Chinese windlass (see diagram) is of the differential motion principle, in that the resultant motion is the difference between two original motions. The hoisting rope is arranged to unwind from one part of a drum or pulley onto another part differing somewhat in diameter. The distance that the load or hook moves for one revolution of the compound hoisting drum is equal to half the difference between the circumferences of the two drum sections.

CH'ING. A Chinese surface measure, legalized in 1908, equal to 614.4 ares or 15.18 acres.

CHIP AND OIL SEPARATORS. Chips from screw machines and other classes of machine tools requiring oil lubrication for the cutting tools, may contain considerable oil even after the chips have been drained by gravity. The average amount of oil on screw machine chips is about 3 gallons per 100 pounds, and by gravity draining only about 30 per cent of this oil is reclaimed; hence, oil extractors are commonly used in machine tool-using plants. These extractors operate on the centrifugal principle. The chips are placed in a perforated pan or basket which is rotated rapidly, thus causing the oil to fly out through the perforations. With these centrifugal oil extractors from 1 to 5 gallons of oil per 100 pounds of chips may be reclaimed. About 2 gallons per 100 pounds is a fair average, but the amount varies considerably, depending upon the extent of previous draining by gravity and the viscosity of the lubricant. By this centrifugal method

practically all of the oil is reclaimed and the process requires only 2 or 3 minutes. Some centrifugal separators are driven by belt and others by a direct-connected electric motor, and the speeds vary from 500 or 600 R.P.M. up to about 1000 or 1200 R.P.M.

CHIP AND WORK SEPARATORS. The machines used for separating chips from screw machine products, etc., usually are either of the blower type which utilizes a blast of air for blowing the chips from the work, or the purely mechanical type which depends entirely upon the reciprocating movement of a screen for separating the chips by a sifting process.

Chip Separators of the Blower Type. — One chip and work separator of the blower or pneumatic type has a work-holding box which is placed in a vibrator. The vibrator spreads out the work and chips and the latter are blown through a hood while the finished parts drop into a pan. This type of machine is built in large and small sizes. The small separator may be used not only for screw machine products, etc., but for watch, clock and other small parts, and also for separating parts from sawdust after tumbling. Parts that are very small and light may be separated by means of an exhauster attachment. In operating this attachment, the material is placed in the work pan and pushed to the inlet opening in the elbow. The chips are then sucked up through the elbow and exhauster, and discharged through the hood, while the finished parts drop through a hole in the bench or table into a box. The lever is operated to regulate the air blast for both blowing and exhausting; the smaller the parts are, the less air is required.

Another blower type of separator operates in the following manner. The work and chips as they come from the screw machine or other machine tool, are put into a hopper at the top of the separator. This hopper is connected by a gate with an inclined slide, and both hopper and slide have a compound vibratory motion which spreads the work and chips out in a thin layer as they move down the slide after the hopper gate is opened. In this slide there is an opening through which the work drops into a tote pan. The chips, however, are prevented from falling through the opening and are floated over it by a draft of air from a centrifugal blower located beneath the hopper and slide. The machine is equipped with a hood to deliver the chips into a wheelbarrow.

Reciprocating Type of Chip Separator. — One design of machine for separating chips from work, operates with a reciprocating motion derived from a crank and rod connected with a "shaker box" which contains the work and is reciprocated on the horizontal ways of the machine stand or base. The shaker box has a wire screen bottom, the mesh of the screen depending upon the kind of chips. This machine is intended for use in combination

with an oil separator for separating chips from finished work, after the oil has been separated from both work and chips.

Separating Monel and Steel Chips. — A magnetic device has been used successfully by one of the large manufacturers of electrical equipment for separating iron and steel chips from monel metal chips, thus effecting a large saving annually due to the reclaiming of the monel metal. Experiments in using the magnetic method were not successful at first, because the monel metal was picked up by the magnet, but by using a rheostat on the magnetic separator and reducing the current to a minimum it was found that the iron and steel chips could be picked up and the monel chips dropped. During cold weather, congealing of the oil on the chips may interfere with clean separation because the oil holds the two metals together; however, this difficulty may be overcome by drying the chips prior to separation.

CHIP CRUSHING MACHINE. This type of machine is used for crushing metal chips and scrap so that a much larger amount may be stored or shipped in a given space; moreover, by crushing the chips a larger percentage of oil can be reclaimed. One machine on the market has a capacity of about 5 tons of steel chips per eight-hour day, and another machine has about the same tonnage capacity per hour.

CHIPS, BRIQUETTING METAL. See Briquetting Metal Chips.

CHISELS, METAL-CUTTING. See Cold Chisels.

CHLORINE. Chlorine is a gaseous chemical element of greenish-yellow color. Its symbol is Cl; atomic weight, 35.46; specific gravity, 2.49 (air = 1); liquefying point, −34 degrees C. (−29 degrees F.); and solidifying point, −102 degrees C. (−152 degrees F.). It is never found in nature in an uncombined condition, but is widely distributed in combination; it is one of the constituents of common salt. Combined with hydrogen, chlorine forms hydrochloric acid. Chlorine is used for many purposes in the industries, and many processes have been devised for its production.

CHLORINE-PROOF CEMENT. A luting material used in electrolytic and chemical plants, which will withstand the action of chlorine, as well as that of acids and alkalies. It consists of one part Portland cement, one part powdered glass, one part silicate of soda, and a small amount of powdered slate. Linseed oil made into a paste with fireclay will also prove impervious to chlorine for a short time.

CHROMATIC SPEED RANGE. The "chromatic speed range" for speed-changing mechanisms is based on the square root of 2, or 1.4142. This range is simply a geometrical progression with a ratio of 1.4142, or a smaller ratio may be used, as 1.189, which is the square root of 1.4142, or

the fourth root of 2. The logarithmic scale gives a number of values the adoption of which as standards in designing speed-changing mechansims has been proposed. These values are approximately as follows: 4.75, 5.67, 6.75, 8, 9.5, 11.3, 13.5, 16, 19, 22.6, 26.9, 32, 38, 45.2, 53.8, 64, 76, 90, 108, 128, 152, 181, 215, 256, 304, 362, 430, 512. The ratio of the geometrical progression, in this case, is 1.189, although the increment of change might be any power of 1.189. With this speed range back-gear ratios of 2, 4, 8, and 16, according to the range desired, could be employed. This point is considered important, because, on some classes of machines, especially lathes, the back-gear ratio can be utilized conveniently for obtaining coarse leads.

CHROMEL. Chromel is the trade name for a high-grade alloy containing, in its best grade, 80 per cent nickel and 20 per cent chromium. Another grade contains 85 per cent nickel and 15 per cent chromium, while still a third grade contains approximately 61 per cent nickel, 25 per cent iron, 3 per cent manganese, and 11 per cent chromium. All other elements are classed as impurities and are held down to a minimum. Chromel alloys have an electrical resistance from fifty to sixty-five times greater than that of copper, depending on the grade of the alloy, and they also have a very high resistance to heat.

The behavior of this alloy under high temperatures makes it suitable for use as a heating element in all kinds of electrically heated devices, from electric toasters to furnaces used for heating steel preparatory to hardening or forging. Iron-free chromel may be found in use in the thermo-couples of nearly all pyrometers that work at a temperature up to 2200 degrees F. This alloy is said to be mainly responsible for the rapid growth of the electric heating industry in which it is used for heating apparatus that operates at temperatures between 1500 and 2200 degrees F. The third grade of the alloy, in which iron is an ingredient, is used extensively in the construction of flat-irons, ovens, and heating devices that operate below a temperature that does not exceed the oxidizing point of the alloy.

CHROME IRON. The term " chrome iron " is sometimes applied to an alloy consisting primarily of iron and chromium. Alloys of this kind and containing from 27 to 30 per cent chromium were developed originally for high-temperature installations, but they also resist corrosion, nitric acid and most organic acids. See Duraloy.

CHROME-TANNED LEATHER. A material used for so-called " steam-proof " belting. Water has little or no effect on chrome-leather belts, and these belts may even be immersed in boiling water for a short time without serious damage to the leather. See Tanning.

CHROMIUM. Chromium is one of the metallic chemical elements; its chemical symbol is Cr, and its atomic weight, 52.0. The specific gravity of the pure metal is 6.9, but the commercial metal has a specific gravity of about 6.5, making its weight per cubic inch equal to 0.235 pound. The melting point of chromium is 1510 degrees C. (2750 degrees F.). Its electrical conductivity (silver = 100) is 16. Chromium is an intensely hard, brittle metal, whiter and more lustrous than iron in its appearance, but slowly oxidizing in the air. It does not occur free in nature, but is found in a number of different minerals. The mechanical importance of chromium is as an alloying metal for steel. *Chromium steels* have remarkable qualities as regards tensile strength and high elastic limit, when properly heat-treated. Chromium, when used in the manufacture of chromium steel, is introduced in the form of a chrome-iron ore, also known as *chromite* or *chromic iron*. This is the chief commercial source of chromium and its compounds.

CHROMIUM IN CAST IRON. See Cast Iron Wearing Properties.

CHROMIUM PLATING. Chromium plating is an electrolytic process of depositing chromium on metals either as a protection against corrosion or to increase the surface wearing qualities. In general, the equipment used is similar to that used for other kinds of electro-plating, but the results are more affected by the temperature of the bath and the current density. The hardest deposit of chromium is obtained at the highest current density that can be applied without "burning." A temperature for the bath of about 45 degrees C. (113 degrees F.) and 100 amperes per square foot gives a very bright deposit. The "throwing power" of the chromium plating process is relatively poor, which means that it is comparatively difficult to deposit the chromium in recesses or on parts of irregular shape. A chromium plated surface can be polished so that it will be more brilliant than nickel and have practically the same reflecting power as a high-grade mirror. A chromium coating can be deposited up to at least 0.005 inch thick, which is thicker than ordinarily required in commercial work; brightness of surface is sacrificed with increase of thickness. Chromium plated surfaces are usually hard and resist tarnishing and corrosion.

Chromium plating can be applied to practically all commonly used metals, with the exception of silver and aluminum, and even aluminum alloy die-castings of certain compositions have been successfully plated with chromium. Only two acids, muriatic and hydrochloric, attack chromium plating and its bright lustrous finish is unaffected by heat up to temperatures of 700 degrees F. The melting point is about 3000 degrees F.

Hardness of Chromium Plate. — Although it is difficult to gage accurately the hardness of chromium plating, scratch tests indicate that it has about

the same hardness as the sapphire. Glass can be scratched readily with the edge of a piece of brass strip stock which has been chromium plated, whereas a similar piece which has been nickel plated will simply slide over the glass.

Chromium Plated Cutting Tools. — Metal-cutting tools which have been built up on their cutting edges by chromium plating have given excellent results. A $\frac{3}{16}$-inch reamer used for reaming holes in a monel metal part, for instance, was brought up to the required size by chromium plating. In this case 0.001 inch of metal was put on. The reamer thus treated shows no sign of wear even though it has already produced several times as much work as the best reamer previously obtainable.

Among the various types of cutting tools which have been chromium plated are taps and forming tools. Manufacturers of bakelite and other phenol products have, in some instances, found it profitable to have their cutting tools chromium plated. The hardness, resistance to corrosion and the smooth finish of chromium plating, which lessens chip clogging, makes chromium plated taps especially well adapted for use on bakelite parts. Chromium plated files have proved excellent for use on soft metals, as they do not clog or load up as quickly as unplated files and hold their edge exceptionally well. Chromium plated rivet spinning tools have been found to stand up from ten to fifteen times longer than the hardest unplated steel tools.

Dies and Metal Spinning Tools. — Dies for molding or forming bakelite products of simple form have been found to give longer service and produce a better finish when chromium plated. The depth of plating for dies of this kind is about 0.002 inch. The low coefficient of friction of chromium plated surfaces undoubtedly contributes much to the success of certain metal-cutting or metal-working tools, such as punches and dies for drawing seamless tubes and shells.

Building Up Worn Plug Gages. — Plug gages which have been worn undersize can be built up by chromium plating and then lapped to size. Any amount of metal up to 0.004 or 0.005 inch can be added to a worn gage. Chromium oxide is used in lapping chromium plated gages, or other parts, to size and for polishing. When the chromium plating of a plug gage has worn undersize, it may be removed by subjecting it to the action of muriatic acid. The gage is then built up again by chromium plating and lapped to size. When removing the worn plating the gage should be watched carefully and the action of the acid stopped as soon as the plating has been removed in order to avoid the roughening effect of the acid on the steel.

Cleaning Work to be Plated. — Work which is to be chromium plated must be clean and free from dirt or grease, the same as when any other finish is to be applied. Parts which have been cleaned for finishing by

nickel plating are generally sufficiently well prepared for chromium plating. An effective method of cleaning greasy or dirt covered parts is to wash them in a 5 per cent sulphuric acid solution.

Chromium Plating Equipment. — In one plant where considerable chromium plating is being done, a lead lined tank provided with steam heating coils is used, and the chromic acid solution for the chromium plating is kept at a temperature of from 105 to 115 degrees F. by the steam coil. A motor generator supplies the direct current at about 6 volts and the amperage or current consumption is regulated according to requirements. The electrical energy used is from twenty to thirty times as large as needed for nickel plating. The exact rate at which the metal is deposited must be determined to some extent by experiment. Large automobile radiator shells, for example, require a current of 750 to 800 amperes. All plating tanks are equipped with an ammeter, a voltmeter and a variable resistance control or rheostat. On being removed from the plating tank, chromium plated parts are washed in tanks of hot water until entirely free from the chromic acid of the plating bath.

CHROMIUM-VANADIUM STEEL. Alloy steels of this class, according to the S.A.E. specifications, contain 0.80 to 1.10 per cent chromium; 0.18 per cent vanadium preferably, and a minimum of 0.15 per cent; 0.50 to 0.80 per cent manganese; a maximum of 0.04 per cent phosphorus, and the same maximum of sulphur; and a carbon content ranging from 0.15 to 1.05 per cent, depending upon the class of steel and its application. Most chrome-vanadium steels contain from 0.20 to 0.50 per cent carbon. Many heat-treated forgings are made from these steels.

CHROMIZING. Chromizing is somewhat similar to the well-known process of calorizing. It consists of packing the material to be treated in a powdered mixture of alumina and chromium — 45 per cent of alumina and 55 per cent of chromium, by weight. The material is usually packed into a tube of iron, which is then heated to from 1300 to 1400 degrees C. in hydrogen, vacuum, or some neutral atmosphere. Chromizing has been used on turbine buckets in order to protect them against corrosion. Chromized iron samples have been tested in comparison with sherardized samples and found to be equal to the latter. By casehardening and heat-treatment chromized iron may be made very hard.

CHUCK CLOSER. An "automatic" chuck closer is frequently used on bench lathes in connection with a turret and double-tool cross-slide, when operating on bar stock. This device is used in place of the regular draw-in spindle, and closes the collet chuck by simply throwing over a hand lever. The chuck-closing mechanism is applied at the rear end of the spindle and takes the place of the usual handwheel. It enables the machine to

be run continuously, as the work may be gripped or released while the lathe is in motion.

CHUCKING MACHINES. Some turret lathes are used exclusively for operating on bar stock which is fed through the hollow spindle and is held by some form of collet chuck located in the end of the spindle, whereas other machines are equipped either for handling bar stock or larger work which must be held in a regular chuck that is screwed onto the spindle. There are also turret lathes which are not arranged for turning parts from bar stock, but are designed exclusively for machining castings or forgings which must be held in a chuck that is screwed onto the spindle. Lathes of this latter class are frequently called *chucking* machines, owing to the fact that the work is always held in a chuck.

Multiple-spindle Chucking Machine. This is an automatic machine provided with a number of spindles, usually four or five, which carry and revolve the tools, while the work being machined is held stationary in a multiple-chuck turret which holds each part in line with one of the spindles and which is automatically indexed, so that the work passes from one spindle to another until it is finished. This type of machine is especially adapted for boring, reaming, and facing operations on castings or forgings which can readily be held in chuck jaws.

CHUCKING REAMERS. Reamers of this class are so named because they are used largely for reaming parts held in the chuck of some machine such as an engine lathe or turret lathe. Chucking reamers are made in two general types: *fluted* chucking reamers and *rose* chucking reamers. The fluted type is used for enlarging drilled holes and finishing them true to size; the rose type is used for enlarging cored or drilled holes and is so constructed that a considerable amount of metal can be removed by it. See Fluted Chucking Reamer and Rose Chucking Reamer.

CHUCKS. Chucks of various designs and types are used on different classes of machine tools, either for holding a part while it is being operated upon or for holding some form of cutting tool. The chucks that are used on lathes and other types of turning machines hold and rotate the work, whereas the chucks of drilling machines hold and rotate drills, counterbores, and other tools. Chucks vary greatly both in regard to their size and design. Some are of special construction and are intended for a limited class of work or for holding one particular part, although most work-holding devices of the latter class are known as jigs or fixtures, rather than chucks. The term " chuck," as applied in the machine shop, usually means a device which not only holds but rotates either the work or a cutting tool, although there are exceptions as, for instance, in the case of planer chucks which are attached to the planer table and travel with it. Most work-holding de-

vices which are classified as chucks have gripping jaws that are adjustable in order to adapt the chuck for holding parts or tools of different sizes. These jaws are operated either by screws, by a combination of screws, or a spiral scroll and gearing, by compressed air, or by the engagement of conical surfaces which serve to move the chuck jaws radially by a wedging action. There are also magnetic chucks which do not require jaws, as the work is held by magnetic force instead of by mechanical means.

CHUCKS, AIR-OPERATED TYPE. Air-operated chucks are used on some turret lathes, especially when a rapid power method of chucking is essential to economical production. Chucks operated in this way are especially desirable when the machining operation is rapidly performed and the work is required in large quantities. Such equipment is particularly adapted for brass work.

CHUCKS, GEAR. Special chucks are commonly used for holding gears, especially when grinding the bores of heat-treated gears to insure accuracy between the bore and the teeth. The chuck may be designed to hold the gear (1) by contact at the pitch line; (2) by contact at the bottom of tooth spaces; (3) by contact with the outside diameter or tops of the teeth. The pitch-line contact may be obtained by means of rolls which serves a gripping jaws. Another type of chuck has accurate gears which serve as jaws and are tightened into mesh with the gear to be ground. The root control, or contact at the bottom of the tooth spaces, is obtained by means of special jaws which are narrow enough to bear only on the root. Some gear chucks for bevel gears have tapering pins for pitch-line contact and others, jaws for engagement at the bottoms of the tooth spaces. A third method consists in clamping the bevel gear against a master gear which meshes with the gear to be ground.

CHUCKS, LATHE. There are three classes of chucks ordinarily used on the engine lathe, known as the independent, universal, and combination types. The *independent chuck* is so named because each jaw can be adjusted in or out independently of the others by turning the jaw screws with a wrench. The jaws of the *universal chuck* all move together and keep the same distance from the center, and they can be adjusted by turning any one of the screws, whereas, with the independent type, the chuck wrench must be applied to each jaw screw. The *combination chuck*, as the name implies, may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects, as it is usually stronger and adapted for holding odd-shaped pieces, because each jaw can be set to any required position. The *collet chuck* is another

class which is commonly applied to tool-room lathes, turret lathes, bench lathes, etc., usually for holding rods or bar stock, which is inserted through the hollow spindle of the machine, so that the end projecting beyond the chuck may be operated upon.

CHUCKS, MAGNETIC. Magnetic chucks are unexcelled for holding a large number of small parts at one time for grinding and are also adapted for a wide range of work. They are made in a variety of sizes and shapes, the form depending upon the type of grinding machine and the shape of the work. The magnetic chuck is a special form of electromagnet which is connected by wires and a control switch with an electric power circuit. The surface, against which the work is held, has a series of positive and negative holes which are separated by an insulating material. When in use, the chuck is clamped onto the table of the grinder, and the work is held by magnetic force when the current is turned on. The rectangular magnetic chuck is the form used on surface grinders of the reciprocating type. Magnetic chucks are made in many different styles and shapes. Some are so arranged that the clamping face can be set at any angle for taper grinding and others have faces that are vertical. There is also the rotary type and other special designs. The rotary form is used when a continuous rotary movement is required, instead of a reciprocating motion.

CHUCKS, QUICK-CHANGE TYPE. The quick-change collet chuck is adapted for both drilling and tapping operations. With one arrangement the drill or tap is held in a collet and, in order to mount the tool in the chuck ready for use, it is merely necessary to grasp a knurled collar and hold it back against the rotation of the spindle. This causes a pair of retaining dogs to be drawn back into the body of the chuck so that the collet can be slipped into place. The knurled collar is then released and the action of a spring forces the dogs inward, so that they engage a groove in the collet and secure it in the chuck.

CHUCKS, VACUUM. See Vacuum Chucks.

CINCINNATI PLAN. A system of engineering education in which the students, taking engineering courses at a technical college, work alternate weeks in regular manufacturing shops and in the school.

CINNABAR. Cinnabar is a very heavy mineral composed of red sulphide of mercury, found in California, Mexico, Spain, Hungary, Chile, and several other places. It is the principal and most valuable of the commercial mercury ores.

CIRCLE. A plane surface bounded by a curved line known as the *periphery* or the *circumference*, all points of which are at an equal distance

from a point within the circle known as the "center." The term "circle" is also used with reference to the periphery or circumference only, without reference to the plane surface enclosed by the circumference. In the mathematical sense of the word, this usage is not correct. The circular line is the "periphery," and the area enclosed is the "circle."

CIRCLE DIVIDING. If there are six divisions, the dividers may be set to the radius of the circle. For any other number of divisions, the distance between the dividing points may be determined by the following rule: Divide 360 by the number of divisions required to obtain the angle between centers of the spaces; find the sine of one-half this angle (by referring to a table of sines) and multiply it by the diameter of the circle upon which the centers of the spaces are to be located. Assume that twenty equally spaced centers are to be located on a circle 10 inches in diameter; then the angle between the centers equals $360 \div 20 = 18$, and the sine of one-half this angle, or 9 degrees, is 0.15643; therefore the distance between the divider points equals $0.15643 \times 10 = 1\frac{9}{16}$ inch, approximately.

CIRCUIT-BREAKERS. A circuit-breaker is a device for automatically opening an electric circuit when a predetermined abnormal condition exists in the circuit in which the circuit-breaker is connected. There are several kinds of circuit-breakers. Those in most common use are the magnetic blow-out circuit-breaker, the air- or carbon-break circuit-breaker, and the oil circuit-breaker. Circuit-breakers are generally arranged to trip under one of the following conditions or some combination of them: Overload, underload, over-voltage, low voltage, and reverse current. The automatic tripping of a circuit-breaker is accomplished by applying or releasing the power of an electromagnet which is excited by current flowing through a coil of wire, or its equivalent, surrounding at least one pole of a magnetic circuit. The magnet coils may be of either one of two classes — current or potential — depending upon the manner in which the coils are connected in the circuit. See Double-pole Circuit-breaker.

CIRCULAR FILE. The circular form of file is intended more particularly for filing soft metal, such as aluminum, solder, babbitt, etc. This type of file is simply a steel disk on the sides of which teeth are cut. When the file is in use, it is mounted on a spindle like a grinding wheel and is rotated by power. A circular file 14 inches in diameter and 1 inch thick is rotated at a speed of about 200 revolutions per minute. The part to be filed is held against the side of the revolving file. There are several annular rows of teeth, the teeth in adjacent rows inclining in opposite directions. The grade of cut is varied to meet different requirements.

CIRCULAR INCH. The area of a circle 1 inch in diameter. One circular inch is equal to one million circular mils, or 0.7854 square inch.

CIRCULAR MEASURE. The system of angular measurement in which the *radian* is used as a unit. This system is generally used in theoretical investigations and in formulas relating to revolving bodies. See Radian.

CIRCULAR MIL. In measuring diameters and areas of electric wires, use is frequently made of the surface measurement *circular mil.* A circular mil is the area of a circle 0.001 inch in diameter; one circular inch equals the area of a circle 1 inch in diameter; hence, 1 circular inch equals 1,000,000 circular mils. A circular inch equals 0.7854 square inch.

CIRCULAR PITCH. The *circular pitch* of a gear tooth is the distance from the center of one tooth to the center of the next, measured along the pitch circle. The circular pitch is at the present time, as a rule, used only in relation to gears with cast teeth which are not afterwards finished or cut. For cut gearing, *diametral pitch* is used almost exclusively; and this latter pitch is used to some extent for cast gearing as well. When the pitch diameter and the number of teeth of a gear are known, the circular pitch is found as follows:

$$\text{Circular pitch} = \frac{\text{pitch diam.} \times 3.1416}{\text{number of teeth}}.$$

CIRCUMFERENCE. The curved line which forms the boundary line of any circular, elliptic or oval surface; specifically, the periphery of a circle.

CISTERN BAROMETER. An instrument for measuring the pressure of the atmosphere, consisting of a glass tube about 36 inches long, hermetically sealed at the upper end at which a vacuum is formed, the remainder of the tube containing mercury. The tube is placed with its open lower end in a cistern or vessel containing mercury, the pressure of the atmosphere being measured by the difference in the height of the mercury in the tube and in the cistern.

CITROËN GEAR. This type of gear might be described as a double herringbone form, as the teeth have a double wave formation such as would be obtained by placing two herringbone gears together. Gears of this type are used to a very limited extent as the herringbone gear has advantages in regard to cutting, and is, at least, equal to the Citroën gear from a practical or operating point of view.

CLACK VALVES. Pump valves of the *clack* or *clapper* type are hinged on one side so that they open and close like a door. The pivot of the hinge sometimes has an elongated hole so that the valve can lift at the hinged end

so as to obstruct the flow of liquid as little as possible. Many valves of the clack form are of metal and have leather faces. When two clack valves are hinged at the center of a valve-seat, the term " butterfly " valve is often used. The *flap valve* is similar to a clack valve, except that it is fastened to one side of the valve opening instead of being hinged, and is formed of material that has sufficient elasticity to bend far enough to give the required port opening. These valves are usually made of rubber.

CLAM-SHELL BRAKE. A block brake provided with two blocks acting one on each side of the brake pulley. It is often used in place of a band brake, over which it possesses the advantage of even wear on the blocks and of a positive release, but it does not have as great a gripping power as a band brake.

CLARK CELL. A primary cell or battery, known as a " standard " cell, used for obtaining a certain standard value of electromotive force under given conditions. It consists of a glass container mounted in a metal case, having insulated binding posts connected to platinum terminals. In one form, mercury, which is the negative electrode, is placed at the bottom of the cell, and a paste of mercurous sulphate and zinc sulphate is placed upon the mercury, the zinc plate, which is the positive electrode, being partly immersed in it, and then saturated zinc sulphate solution is put on top, the latter acting as the electrolyte while the paste acts as the depolarizer. The surface is usually covered with cork and the cell sealed. Platinum wire led through the bottom of the cell forms the terminal for the negative electrode, and insulated wire led through the cell forms the terminal for the positive electrode. The electromotive force is 1.43 volts at 15 degrees C. (59 degrees F.).

CLAY CRUCIBLE. A pot or container used in the steel industry in the manufacture of crucible steel, having a capacity of from 75 to 100 pounds of metal. Clay crucibles are made of a high quality of clay mixed with about 5 per cent of powdered coke. They must be heated slowly to prevent cracking, and must be recharged while hot.

CLEANING MACHINES. Machines for cleaning and drying screw machine parts, stampings, etc., are made in several different designs. One machine consists of a revolving horizontal cylinder through which the parts pass during the cleaning or drying operation. As the parts pass from a chute into one end of the cylinder they are moved along by a helical or screw-shaped conveyor and the cleaning solution is scooped up from a tank below and poured on to the work. As the cylinder rotation continues, the work advances and is further cleansed by fresh solution and finally, when cleaned, reaches a perforated section of the cylinder. The solution then drains back

into the tank. The parts are next rinsed with water and then pass into a larger perforated section where they are dried by means of hot dry air obtained by means of steam coils and a blower. Finally the parts pass out at the discharging end, the entire operation having been continuous and automatic.

CLEANING METALS, ELECTROCHEMICAL. See Electrochemical Cleaning.

CLEANING SOLUTION, SODA. See Soda Cleaning Solution.

CLEARANCE. "Clearance," also known as "allowance," is a term signifying the difference between working parts to admit of motion and lubrication. In other words, the clearance is the space between adjacent parts, whether this space is allowed merely to avoid interference, or in order to obtain definite classes of fits. The clearance allowed between different parts is governed by the conditions under which the parts are to work.

Clearances are vital factors in interchangeable manufacturing. Fits can be secured without interchangeability, but the latter cannot be maintained without proper clearances. It is self-evident that a certain space must be left between operating parts. The minimum clearances should be as small as the assembling of the parts and their proper operation under service conditions will allow. The maximum clearances should be as great as the functioning of the mechanism permits. The variation between a maximum and a minimum clearance determines the manufacturing tolerance. It is clear, then, that determining at the outset the permissible clearances establishes also the extent of the tolerances which control the final inspection.

Clearances should be one of the principal considerations in developing the manufacturing design. This design should aim to allow the greatest possible amount of clearance between companion parts. The more the design lends itself to this end, the greater the economy of manufacture and the greater the degree of interchangeability obtainable. In determining which parts of a mechanism can be made interchangeable, this matter of permissible clearances plays the largest part. A mechanism which is so designed that it cannot permit fairly liberal clearances is not a suitable one to be manufactured on a strictly interchangeable basis with the standard equipment now available. Every operating part of a mechanism must be located within reasonably close clearances in each plane. After such requirements of location are met, all other surfaces should have liberal clearances, unless the factor of strength is the controlling one.

CLEARANCE AIR. The air which remains in the cylinder of an air compressor when the piston is at the extreme end of the stroke, and which cannot be expelled on account of the clearance between the piston and the

cylinder head is known as clearance air. The clearance in air compressors commonly varies from 1 to 3 per cent of the piston displacement.

CLEARANCE FOR CUTTING TOOLS. In order that the cutting edge of a turning tool, drill, milling cutter or other edged tool for metal cutting, may work without interference, it must have clearance; that is, the surface below or back of the cutting edge must be ground to a certain angle so that it will not rub against the work and prevent the cutting edge from entering the metal. This clearance should be just enough to permit the tool to cut freely. A clearance angle of 8 or 10 degrees is about right for lathe turning tools. A turning tool for brass or other soft metal, particularly where considerable hand manipulation is required, could advantageously have a clearance of 12 or 14 degrees, as it would then be easier to feed the tool into the metal; but the clearance for various classes of metal-cutting tools should be just enough to permit them to cut freely. Excessive clearance weakens the cutting edge and may cause it to crumble under the pressure of the cut. The angle of clearance is about 4 or 5 degrees for planer tools, which is much less than that for lathe tools. This small clearance is allowable because a planer tool is held about square with the platen, whereas a lathe tool, the height of which may be varied, is not always clamped in the same position. A lathe tool also requires more clearance because it has a continuous feeding movement, whereas a planer tool is stationary during the cut, the feed taking place just before the cut begins.

CLEARANCE IN ENGINE CYLINDERS. The clearance is the space between the cylinder head and the piston, when the latter is at the end of its stroke; it also includes that portion of the steam port between the valve and the cylinder. Clearance is usually expressed as a percentage of the piston-displacement of the cylinder, and varies in different types of engines. Ordinarily the percentages are about as follows: For Corliss engines, 1.5 to 3.5; engines for medium speeds, 3 to 8; high-speed engines, 4 to 10. A large clearance is evidently objectionable, because it represents a space which must be filled with steam at boiler pressure at the beginning of each stroke, and from which but a comparatively small amount of work is obtained. As compression increases, the amount of steam required to fill the clearance space diminishes, but, on the other hand, increasing the compression reduces the mean effective pressure.

CLEVELAND GRIP SOCKETS. The grip socket known as the *Cleveland grip socket*, is designed to hold and drive taper shank drills and other tools provided with taper shanks. A groove is milled in the shank of the drill or tool and a key which is let into the body of the socket fits into the groove and is locked securely in place by turning a revolving collar one revolution. When the key is locked, it is impossible for the tool to slip in

the socket or to be pulled out until the collar is turned back again to release the key.

CLOCK BRASS. A brass suitable for the gears in clocks, containing about 60 per cent of copper, a small percentage (not exceeding 1.5 per cent) of lead, and the remainder zinc.

CLOSED-CIRCUIT OILING. A method of bearing lubrication generally used for high-speed work, in which the oil is used over and over again. After dropping off from the journal to a collecting reservoir, the oil is filtered and used again by being automatically supplied to the journal at a suitable point. A cooling arrangement is sometimes fitted to the reservoir, so as to remove the heat from the oil.

CLOSED FEED-WATER HEATER. A device in which the feed water for boilers is heated by passing it through a series of brass or copper tubes surrounded by steam. There is no intermingling of the feed water and the exhaust steam used for heating it.

CLOSER OR STEP CHUCK. See Step Chuck.

"CLOUDBURST" HARDENING PROCESS. See Hardening Steel by Cloudburst Process.

CLUSTER GEARS. The term "cluster gears" is applied when two or more gears are formed on one solid piece. Cluster spur gears are commonly used in automobile transmissions and other geared speed-changing mechanisms because they are stronger and more compact than single gears fastened together.

CLUTCHES. A clutch is a form of coupling which is designed to connect or disconnect a driving or driven member for starting or stopping the driven part. A clutch consists principally of two main sections which are engaged or disengaged either at will by a hand-operated controlling device, or automatically by the action of some power-driven mechanical apparatus, such as a cam connected by suitable means with the shifting clutch member. There are several distinct types of clutches which are made in a great variety of designs. The common types of clutches may be divided into two general classes; namely, (1) those having teeth which interlock, or positive clutches, and (2) those which transmit motion from the driving to the driven part of the clutch by frictional contact.

When motion is transmitted from the driving to the driven parts of a clutch simply by frictional contact, the load may be started gradually and without shock, such as often occurs when a positive clutch is engaged. The different types of friction clutches vary in regard to the form of the friction surfaces and with respect to the kinds of material used to obtain sufficient

frictional resistance. The frictional surfaces may be either conical or cylindrical, or in the form of one or more flat rings or disks.

Conical Clutches. — A conical clutch is so designed that motion is transmitted by the frictional resistance of engaging conical surfaces. The effectiveness of any friction clutch as a transmitter of power varies with the coefficient or degree of friction between the engaged surfaces. The frictional surfaces may both be of metal, but, in many cases, one member has a metal surface and the other is partially or entirely covered with some material such as leather or an asbestos fabric. The cast iron and leather combination is common, and pieces of cork inserted in holes drilled in one member is another common method of increasing frictional resistance. It is common practice to maintain the driving and driven members of friction clutches in engagement by means of springs which are compressed in order to release the clutch. The angle of the conical surfaces is usually about 12 or 13 degrees. The conical type of friction clutch is simple in construction but rather bulky or large when compared with other types of equal capacity as transmitters of power.

Expanding Type of Friction Clutch. — The radially expanding type of clutch is a form that has been widely used, the details of the design being varied more or less. A typical design consists of an outer casing in which there are two expanders or segment-shaped pieces connected by right- and left-hand screws, respectively. These screws are attached to levers, which, in turn, are connected to the sliding sleeve, by links, thus forming toggles between the sleeve and the screws. The two expanders and the toggle mechanism are caused to revolve with the shaft by a central driving hub. The clutch is operated by shifting the sliding sleeve and toggles; this movement turns the screws having right- and left-hand threads far enough to either expand the inner members tightly against the outer casing or to withdraw them from frictional contact. The expanders may be lined with maple grips, to increase the frictional resistance.

Ring and Disk Clutches. — Many clutches of the friction type transmit motion from the driving to the driven side through the frictional resistance of rings, plates, or disks which are pressed together, the resistance being between the flat surfaces of the rings or disks which are thus held in contact. Some clutches of this general type have a few comparatively heavy rings, whereas others are equipped with a larger number of thin rings. By using quite a number of disks or rings instead of one or two, the diameter of the clutch may be reduced without sacrificing the contact area or the amount of frictional surface. Various combinations of materials are used for the disks of multiple-disk clutches. One set, for example, may be of soft steel and the other of phosphor-bronze, and in other types one set of disks is faced with some special friction material such as asbestos wire fabric, as

in the case of dry plate clutches, the disks of which are not lubricated like those of a clutch having, for example, the steel and phosphor-bronze combination.

CLUTCHES THAT AUTOMATICALLY DISENGAGE. The clutches used on power presses and some other kinds of machines, are designed to automatically disengage after making one or more revolutions. The clutch connects the fly-wheel or driving gear of the press with the driven shaft, whenever it is tripped, by pressing down a foot-treadle. As long as this treadle is held down, the clutch remains in engagement and the press continues to run; if the treadle is released, the clutch is disengaged when the ram or slide of the press is approximately at the top of its stroke. The downward movement of the treadle releases a pin, key, or some other form of locking device which quickly engages the driving member; when the treadle is released, the locking device encounters some form of trip or cam surface which withdraws it and stops the press. There are many designs of clutches of this general type. See also Induction Clutch; Magnetic Clutch.

COAL. Coal, in the ordinary sense of the word, includes a number of carbonaceous materials used as fuel. The different kinds of coal all contain carbon, hydrogen, oxygen, and nitrogen, forming a carbonaceous or combustible portion, and also some matter which remains after the combustion in the form of ash. The amount of ash varies considerably in different kinds of coal. The nearest approach to pure carbon is furnished by anthracite coal which contains over 90 per cent of this constituent. Coals of this kind burn with a very small flame, producing intense local heat and no smoke. Bituminous coal contains from 50 to 85 per cent of carbon. Lignite or brown coals have a comparatively low percentage of carbon, usually not exceeding 50 per cent, while the oxygen and hygroscopic water is high.

The U. S. Geological Survey classifies coal as anthracite, semi-anthracite, semi-bituminous, bituminous, sub-bituminous, and lignite.

Anthracite contains over 90 and sometimes up to 97 per cent of carbon and has a heating value per pound of combustible of from 14,500 to 15,000 B.T.U. Anthracite is hard and shiny, is slow to ignite, and burns slowly.

Semi-anthracite coal is similar to anthracite. It contains from 85 to 90 per cent of carbon and has a heating value, per pound of combustible, of from 14,500 to 15,500 B.T.U. It is not as hard as regular anthracite, is less shiny, and burns more rapidly.

Semi-bituminous coal contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U., per pound of combustible. This coal is softer than the anthracites and has a tendency to produce more smoke, but on account of its high heating value it is one of the best coals to use for power plant purposes.

Bituminous coal, generally known as soft coal, contains from 50 to 75 per cent of carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. The heating value per pound of combustible is from 13,500 to 15,500 B.T.U. Coal of this kind gives out large volumes of smoke, and requires special care in firing and furnaces constructed so as to prevent smoke as far as possible.

Lignite, also known as *brown coal*, contains less than 50 per cent of carbon and over 50 per cent of volatile matter, and has a heating power per pound of combustible of from 11,000 to 13,500 B.T.U. Two types of lignite are recognized: (1) *sub-bituminous* coal, also known as *lignite, black lignite, brown coal, lignitic coal*, etc.; this kind resembles bituminous coal, is black and shiny, but disintegrates more rapidly than bituminous coal when exposed to the air, and its heating value is not as high as that of bituminous coal; (2) *lignite*, also known as *brown lignite* or *brown coal*, is distinctly brown in color and has a woody structure. It carries from 30 to 40 per cent of moisture and has a lower heating value than any of the other coals. It is, in fact, intermediate between coal and peat, and is fragile, splitting into small pieces when exposed to the air.

COAL AND GAS FUEL-OIL EQUIVALENTS. See Fuel-oil Coal and Gas Equivalents.

COAL COMBUSTION. See Combustion of Coal.

COAL DUST AS FUEL. The fact that dust will burn with great rapidity accounts for the attempts to make use of pulverized fuel, which may be burned without smoke and with high economy. This fuel, instead of being introduced into the firebox in the ordinary manner, is first reduced to a powder by pulverization, and, in place of the ordinary boiler firebox, a combustion chamber is used in the form of a closed furnace lined with fire-brick. This furnace is provided with an air injector having a nozzle which throws a constant stream of powdered fuel into the chamber, spraying it throughout the whole space of the firebox. This powder may be ignited by first raising the lining of the firebox to a high temperature by an open fire. The combustion of the powdered fuel then continues in an intense and regular manner under the action of the air current which carries it into the combustion chamber. It is probably the most economical method of burning coal as far as fuel efficiency alone is concerned. It is the most expensive method in regard to the auxiliary equipment and labor required and the necessity of various features being carefully looked after. The coal must have about 30 per cent of volatile matter and be pulverized to a certain degree of fineness in order to ignite satisfactorily. It cannot be stored for more than about a day without danger of spontaneous combustion. This makes necessary an elaborate system of conveyors to carry the coal from the

pulverizers to the furnaces. In general, this is an impracticable system for small installations, but may be sufficiently economical to be very desirable for large installations.

COAL GAS. See Gas Production.

COAL STORAGE. Soft coal should preferably be stored in pockets or bins of concrete or brick. If a roof is provided to keep out rain and snow, it should be of non-combustible construction. The space between the roof and the top of the coal should be properly ventilated to avoid danger of explosion of gases. A cone-shaped and elevated bin in which coal is fed in at the top and removed at the bottom is regarded as the ideal arrangement. Spontaneous combustion is more to be feared from recently mined coal than from that which has been out of the mine for some time. The following precautions, however, are necessary to avoid the danger of spontaneous combustion in *all* soft coal storage.

1. Coal should not be piled against mill buildings or around combustible building supports or close to a frame building.

2. Storing near external sources of heat should be avoided, even though such heat may be moderate.

3. Not more than 500 tons should be placed in a pile, and 25 feet of clear space should be kept between piles.

4. Piles should not be more than 10 or 12 feet deep, and no part of the pile more than 10 feet to an air-cooled surface.

5. Alternate wetting and drying should be avoided, and if coal is received wet, it should be placed around the edges of the pile where air can get to it freely and where other coal will not be piled over it.

6. Lump and fine coal should be mingled as much as possible to avoid lumps forming air passages which facilitate the spread of fire.

7. Air should not be admitted to the interior of the pile through interstices around piers, timbers, etc.

8. Pipes about 1 inch in diameter should be located vertically in piles, one to each 300 to 400 square feet of area (three or four pipes ordinarily will be satisfactory for a 500-ton pile). The lower ends of these pipes should be at varying distances from the bottom of the pile. A thermometer should be lowered into these pipes at weekly intervals to ascertain the temperatures existing inside the pile. Pipes should be capped and plugged when not in use in order to prevent admission of air to the bottom of the pile.

COAL STORAGE UNDER WATER. According to investigations carried out by the Bureau of Mines, the expense of under-water storage equipment is not justified except as a preventive of fires from spontaneous combustion. In fact, the amount of deterioration of coal during storage has been commonly overestimated. While underwater storage of coal prevents

deterioration of calorific value, in five years' storage in the open air Pittsburg coal deteriorated only about 1 per cent in one year, 2 per cent in two years, and from 2.5 to 3 per cent in five years. Pocahontas coal — a semi-bituminous type — lost less than 1 per cent of its heating value during two years of outdoor exposure. The Sheridan, Wyoming, sub-bituminous coal, known as "black lignite," lost 3 to 5.5 per cent of its heat value in two and three-fourths years of outdoor storage, the greater part of this loss being in the first nine months. The lumps became badly cracked so that they broke up on handling. By the use of bins with air-tight bottoms and sides and a protecting layer of fine slack, the loss in heat value in one year can be kept below 3 per cent and the physical deterioration will thus be largely prevented.

COARSE METAL. A mixture of copper and iron sulphide obtained in the smelting of copper ore in a blast or reverberatory furnace. It is also known as *matte*.

COARSE THREADING ATTACHMENTS. To avoid the difficulties connected with cutting threads of large lead, some lathes are equipped with a coarse screw-cutting attachment. One such arrangement is as follows: On the usual reversing shaft, and inside of the headstock, there is a sliding double gear so arranged as to be engaged with either the usual gear on the spindle or with a small pinion at the end of the cone. The gears are so proportioned that the ratio of the two engagements is as 10 to 1; that is, when engaged with the cone gear (the back-gears being thrown in), the mating gear will make ten revolutions to one of the spindle, so that, when the lathe is ordinarily geared to cut one thread per inch, it will, when driven by the cone pinion, cut one thread in ten inches. This construction dispenses with the extra strain on the reverse gears due to moving the carriage at the rapid rate that would be necessary for such a large lead, when not using an attachment. These attachments are not only used for the cutting of coarse screws, but for cutting oil grooves on cylindrical parts.

COATINGS FOR LAYING OUT LINES. Common chalk or a mixture of whiting and alcohol is often employed in laying out rough castings in order that the lay-out lines may be easily seen. The whiting is sometimes mixed with water, but alcohol is preferable because it will dry quicker and does not tend to rust the surface. This mixture may be applied with a brush. For many purposes the surface can be coated satisfactorily by simply rubbing dry chalk over it. However, as lines which are drawn on a chalked surface are quite easily obliterated, permanence is given them by marking their location with small centerpunch marks. When iron or steel surfaces have been machined, they can be coated by moistening the surface and rubbing it with a piece of copper sulphate or blue-stone. The following

copper-sulphate solution gives even better results: To 4 ounces of distilled or rain water, add all the copper sulphate that the water will dissolve; then add ten drops of sulphuric acid. Test by applying to a piece of steel and, if necessary, add four or five additional drops of acid. The thin copper film which is deposited by this solution makes it possible to easily see fine lines because of the difference in color between the copper and the metal beneath. For this reason, the copper-sulphate solution is very often used, especially when fine lines are required. The surface to be coppered should be polished and free from grease. Apply the solution with clean waste, and, if a bright copper coating is not obtained, add a few more drops of the solution; then scour the surface with a fine emery cloth and apply immediately a small quantity of fresh solution.

COBALT. Cobalt is one of the metallic elements; its chemical symbol is Co, and its atomic weight, 59. Its specific gravity varies from 8.52 to 8.95, according to its state of purity. The specific gravity of unannealed pure metal is 8.79 and of annealed pure metal, 8.81, whereas the commercial metal has a specific gravity of about 8.65. Its melting point is 1490 degrees C. (2714 degrees F.). The electric conductivity (silver = 100) is about 17. It is very magnetic, and ranks next to iron as a magnetic metal. The mean specific heat between 15 and 100 degrees C. (59 and 212 degrees F.) is 0.105. The hardness of cast cobalt is considerably greater than that of iron and nickel. The tensile strength of pure cast cobalt is about 34,000 pounds per square inch. This strength is raised to 37,000 pounds per square inch by annealing, and may be increased to 100,000 pounds per square inch by rolling and drawing into wire. The elastic limit is fairly close to the breaking load, and is considerably greater, proportionately, than that of iron or nickel. The addition of carbon to cobalt increases its tensile strength. The compressive strength of pure cast cobalt is 120,000 pounds per square inch. The impurities of commercial cobalt (up to 0.3 per cent of carbon in addition to small percentages of nickel, iron, sulphur, and silicon) raise the compressive strength to 175,000 pounds per square inch. The elastic limit in compression is, however, not more than about 50,000 pounds per square inch.

COBALTCROM STEEL. A tungstenless alloy or high-speed steel is known as cobaltcrom steel because it contains cobalt and chromium in addition to carbon. A typical steel of this kind contains about 1.5 per cent carbon, 12.5 per cent chromium, and 3.5 per cent cobalt. This steel can be hardened at a temperature of about 1830 degrees F., which is considerably lower than that required for high-speed steels containing tungsten. This lower hardening temperature for cobaltcrom is considered an important advantage in heat-treating tools having fine edges, such as milling cutters, reamers, taps, etc. Cobaltcrom tools are held at a temperature of about

1830 degrees F. until thoroughly "soaked"; then the temperature is reduced about 50 degrees, the tools are withdrawn from the furnace and allowed to cool in the atmosphere until the red color disappears, when the tools are quenched in oil until cold. Tools subject to shocks, such as pneumatic rivet sets, shear blades, etc., should be heated slowly to 1650 degrees F., the temperature then being reduced to about 1610 degrees F. The tool is then removed and permitted to cool in the atmosphere. There is no appreciable scaling in the heat-treatment of cobaltcrom steel. This steel can be cast in molds for making milling cutters, reamers, etc., in order to avoid fluting operations and permit finishing the tools by grinding.

COEFFICIENT. In general a coefficient is a number prefixed to some other quantity by which this quantity is multiplied. In algebraic expressions, it is the number written at the left of a symbol and serves as a multiplier. Hence, in the expression "3a," the figure "3" is the coefficient. A coefficient may also be expressed, in algebra, by a letter.

COEFFICIENT OF EXPANSION. Coefficient of linear expansion is the amount of expansion per unit of length due to an increase in temperature of one degree. The coefficient of cubical expansion is the amount of expansion per unit of volume for an increase in temperature of one degree. See Expansion.

COEFFICIENT OF FRICTION. The coefficient of friction is the ratio between the resistance to motion of a body due to friction, and the perpendicular pressure between the sliding and fixed surfaces. See Friction.

COILING SPRINGS. See Spring Coiling.

COINING PRESSURES. Special embossing or coining presses are required for many embossing operations in the manufacture of medals, jewelry, coins, silverware, etc. For such work as embossing coins or medals, enormous pressures are required in order to make the metal flow into every minute impression in the coining punch and die. The following pressures are required for embossing United States currency: Silver dollar, 160 tons; gold eagle, 110 tons; silver half-dollar, 98 tons; gold half-eagle, 60 tons; silver quarter-dollar, 60 tons; nickel, or five-cent piece, 60 tons; copper cent, 40 tons; dime, 35 tons. It will be noted that the gold half-eagle, silver quarter, and five-cent piece require the same pressure, although the sizes and weights differ greatly, thus indicating the comparative coining properties of gold, silver, and nickel.

A sharp impression depends upon pressure but also to a very great extent upon die construction. Fifty tons can bring up a sharper, better looking job than five hundred if the dies are arranged to pinch just where the sharp lines are desired, and relieved elsewhere, so that the metal can flow.

COINING PROCESS OF FORGING. See Forging by Coining Process.

COKE. Coke is a product obtained by heating coal in air-tight retorts to such a temperature that the volatile constituents are driven off; hence, coke consists mainly of carbon, together with the incombustible materials or ash contained in the coal, and also small amounts of oxygen, hydrogen, and nitrogen, generally not exceeding 2 or 3 per cent. Coke, when produced rapidly and at a low heat, as in gas making, is of a dull black color, igniting with comparative ease, but when produced by long-continued heat, as in making coke for iron and steel melting, it is hard and dense, has a brilliant luster and silver-gray color, and will only burn in furnaces provided with strong draft. This quality is brittle and hard. One pound of coal will yield from 0.35 to 0.90 pound of dry coke, depending upon the kind of coal from which it is made. Coke is an important fuel in blast furnaces and foundries, but its cost is high, and for that reason it is not used for power plant purposes. Coke is classified either as foundry coke or furnace coke.

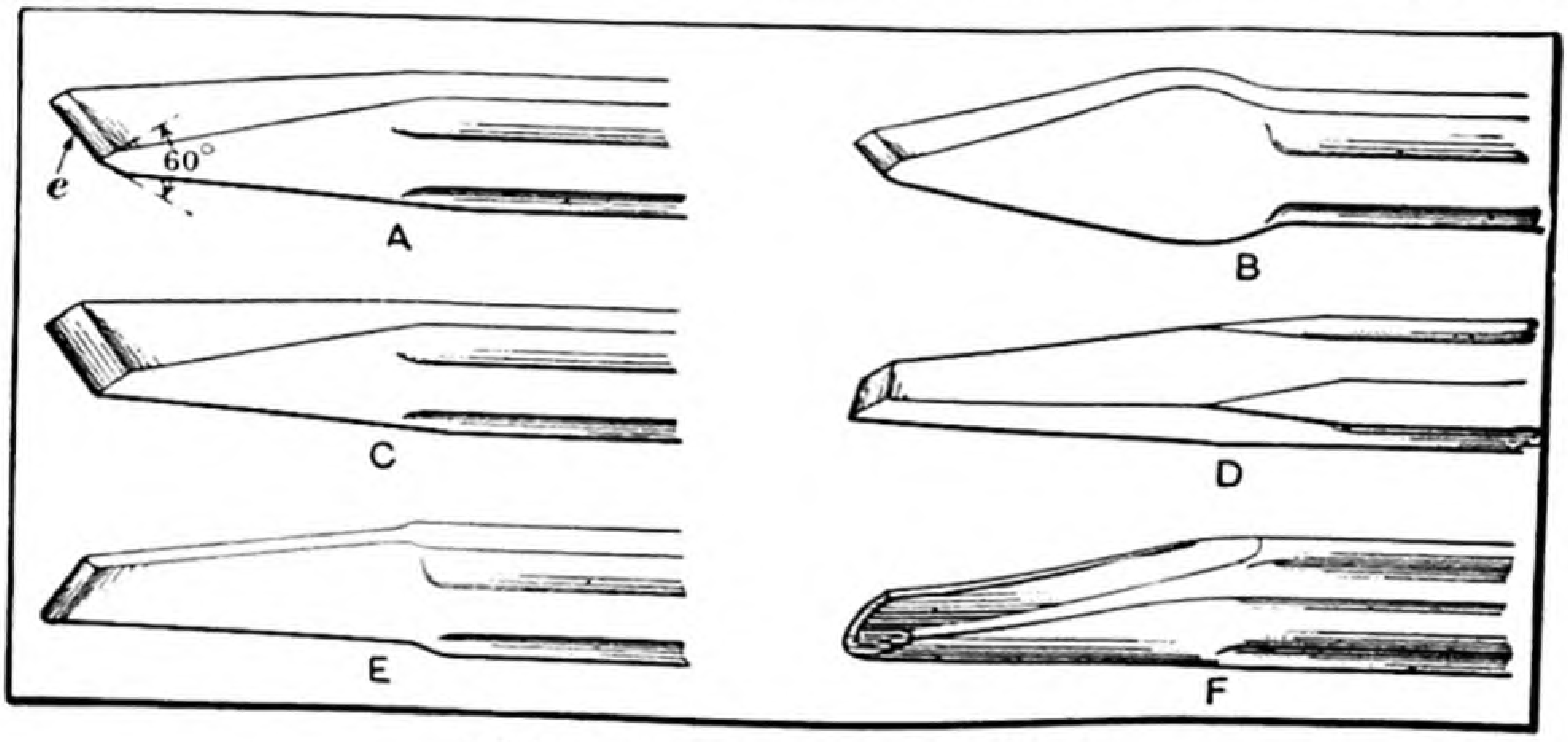
Foundry coke is a hard coke used in cupola furnaces for melting iron, and in large forge furnaces for heating iron and steel. It is dense, has a brilliant luster and silver-gray color, and will only burn in a furnace provided with strong draft. Generally, only coke that has been burned for seventy-two hours, while making, is classified as foundry coke.

Furnace coke is sometimes used in cupola furnaces, but is mainly employed for the melting of ore in blast furnaces. While being made it is burned for forty-eight hours. The standard quality should not contain more than 13 per cent of ash or 1 per cent of sulphur. When containing more than 1.2 per cent of sulphur, it is known as *smelter coke.*

COKE BREEZE. Pulverized coke mainly used for covering the bottoms of soaking pits and crucible furnaces for protecting the brickwork. It is also known as *coke dust.*

COKING COAL. Coke is the fuel commonly used in blast furnaces, and its purity, strength to resist crushing excessively under the blast furnace load, and porosity to permit free circulation of the gases, are important qualities which depend upon the kind of coal used in making the coke. The difference between coking and non-coking bituminous coals has been explained as follows: If the tars of the coal fuse and run at a temperature lower than that at which they volatilize or are driven off as a gas, then the coal may be said to be a coking coal. In this event, the freed tars permeating the fuel bed induce the formation of coke masses by closure of fuel particles and exclusion of air. Conversely, if the tars of the coal are of such composition that they volatilize and are driven off as a gas before they fuse and run through the fuel bed, the coal is then said to be a non-coking or a free-burning coal.

COLD CHISELS. The various types of "cold chisels" commonly used for chipping metals are shown in the illustration. The *flat chisel* *A* is used for a general class of work. The cutting edge *e* is either ground straight for light work or made slightly convex for heavy chipping to prevent the corners from breaking. The included angle at the end should be about 60 degrees, although a greater or less angle is advisable when the metal is either exceptionally hard or soft. A *cape chisel* is shown at *B*. This has a narrower cutting point than the flat chisel, and is used principally for cutting grooves, etc. The *side chisel* *C* differs from the flat type *A* in that it is ground and beveled on one side only, which permits it to be used on surfaces which could not be reached with a dougle-angle end;



Different Types of Cold Chisels

it is also used for chipping the sides of keyways, slots, etc. The *diamond point* shown at *D* is adapted to chipping V-grooves, squaring corners, etc., while the grooving chisel *E* is for cutting oil grooves or for similar work. The *half-round chisel* *F* is known as a gouge, and, as its shape indicates, is used on curved surfaces.

COLD-DRAWING. Cold-drawing, frequently, but erroneously referred to as cold-rolling, is a process to which round, square, or hexagonal bars may be subjected in order to improve the physical properties of the surface, to produce bars of accurate dimensions, and to obtain smooth, even surfaces. The process is briefly as follows: The ordinary hot-rolled bars are first pickled in order to remove the scale. They are then cold-drawn through dies and straightened.

Very little bar stock is cold-rolled today, and although the term "cold-rolled" is still generally used, nearly all the material known as "cold-rolled" is actually cold-drawn. A few manufacturers cold-roll bars over $4\frac{1}{2}$ or 5 inches in diameter, but the general practice on large-diameter bars, especially shafting, is to turn and polish rather than to cold-roll. The largest tonnage of cold-rolled material is in strip stock.

Objects of Cold-finishing. — The objects of both cold-drawing and cold-rolling may be one or more of the following: (1) To secure accuracy of size; (2) to obtain a smooth, even surface; (3) to produce thin, complicated sections; or (4) to affect the physical properties.

Dies for Cold-drawing. — The dies are generally made of a special alloy tool steel that is very high in carbon, some analyses running as high as 2 per cent. Dies for rounds are solid; those for squares, hexagons, and flats are made up of sections, as are most dies for special sections. The Brinell hardness will run from 500 to 600, the harder die being desired for the smaller sizes. The life of a die averages about twenty-five coils on alloy-steel-wire sizes. On bars 20 to 30 feet in length, the average life will be about 500 bars.

Drawing the Steel. — The drawing machines are horizontal benches, driven by individual motors. The grip or jaws, which take hold of the pointed end of the bar, engage with an endless chain which draws the material through the die. For wire sizes or coils, two types of drum machines are used. On one the axis of the drum is horizontal. This is used for the larger sizes of coiled stock — from about $\frac{1}{2}$ inch to 1 inch; it is generally called a "bull block." The drums for drawing smaller sizes (from $\frac{3}{8}$ inch down) have the axis of the drum vertical. These are the wire blocks. In wire mills, one operator may have charge of a number of drums, just as in a machine shop, one man may operate several automatic machines.

Reduction in Drawing. — The draft or reduction per pass varies with the size, analysis, and finish desired. The usual practice is to reduce the diameter $\frac{1}{16}$ inch on sizes down to $\frac{5}{16}$ inch. Under $\frac{5}{16}$ inch, the reduction is generally $\frac{1}{32}$ inch. This applies to such steels as screw stock, whether drawn in the hot-rolled, annealed, or heat-treated condition. In some cases, the reduction will be greater than $\frac{1}{16}$ inch, and at other times less than $\frac{1}{32}$ inch.

Finishing the Bars. — After the material comes from the draw-bench, it must be straightened and cut to length. Straightening is most often done in a roll straightener, of which there are several types. In one type, the rolls that do the straightening revolve about the bar as it is fed through the machine. In another, the bar rotates as it moves between the rolls. The principle is that of deflecting the bar, first in one direction and then in the opposite direction, equal distances. The straightening also increases the smoothness of the bar; but if a high polish is desired, the bar will have to be passed through the machine several times.

Effect on Physical Properties. — The effect of cold-drawing upon the physical properties of carbon steel is to increase the elastic limit 60 to 100 per cent and the ultimate strength 20 to 40 per cent, and to decrease the elongation and reduction of area. The effect of cold-drawing upon hot-rolled alloy steel is not so marked, but it causes an appreciable increase in the elastic

ratio. The difference is not so great when the bars are heat-treated. Generally, alloy steel heat-treated bars, after cold-drawing, will show an increase of 10 to 25 per cent in elastic limit and ultimate strength, and a decrease in the elongation and reduction of area.

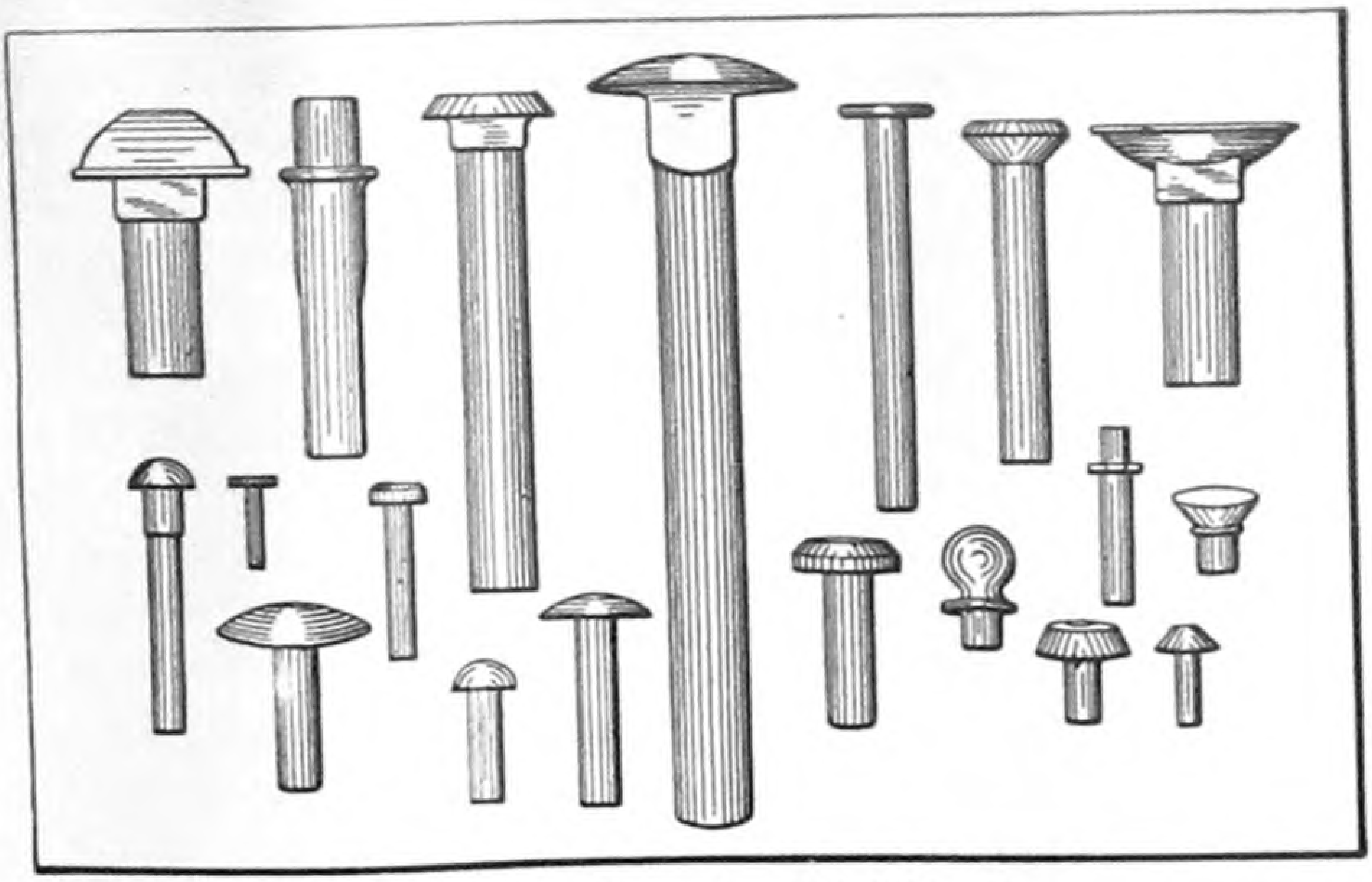
Tolerances. — The tolerances for cold-drawn shafting usually vary from 0.002 to 0.004 inch, the tolerance increasing with the size of the shafting. For shaft diameters less than $2\frac{1}{2}$ or 2 inches, the tolerance according to common practice would be minus 0.002 or 0.0025 inch and the plus tolerance, zero. For larger shafts, the minus tolerance would be 0.001 or 0.0015 inch per inch of shaft diameter and the plus tolerance, zero.

COLD-FORGING. The cold-forging process is applied in producing certain odd-shaped pieces that are squeezed to shape from solid metal in making parts for adding machines, sewing machines, speedometers, typewriters, electrical equipment, toys, and novelties. On this class of work, the blank should be so designed that no more metal has to be squeezed down than is absolutely necessary. Note also that in the pieces which have a boss, hub, or other portion higher than the rest of the piece and left so by squeezing down the metal around it, there is a tendency in the process to drag down the corners and edges of such high parts. To minimize this tendency, it is often advisable to use a medium hard stock, and if necessary, arrange the dies so that they will strike the high part at the end of the stroke and size it off. There may be considerable variation in the pressure required for this work on account of the area and thickness relation. For practical cases, however, with a free flow relief all around, 100 tons per square inch or higher on the area squeezed may be required for steel, and 75 tons per square inch for copper. See also Cold-pressed Forgings.

COLD-HEADING. The operation of forming the heads of rivets, wood-screw blanks, machine-screw blanks, and similar products, by upsetting the ends of the wire lengths while cold, is known as *cold-heading.* The machines to which the wire is fed from a coil, and in which it is cut off and headed, are known as *cold-headers.* A general idea of the classes of work done by cold-heading may be obtained from the illustration, which shows some miscellaneous examples.

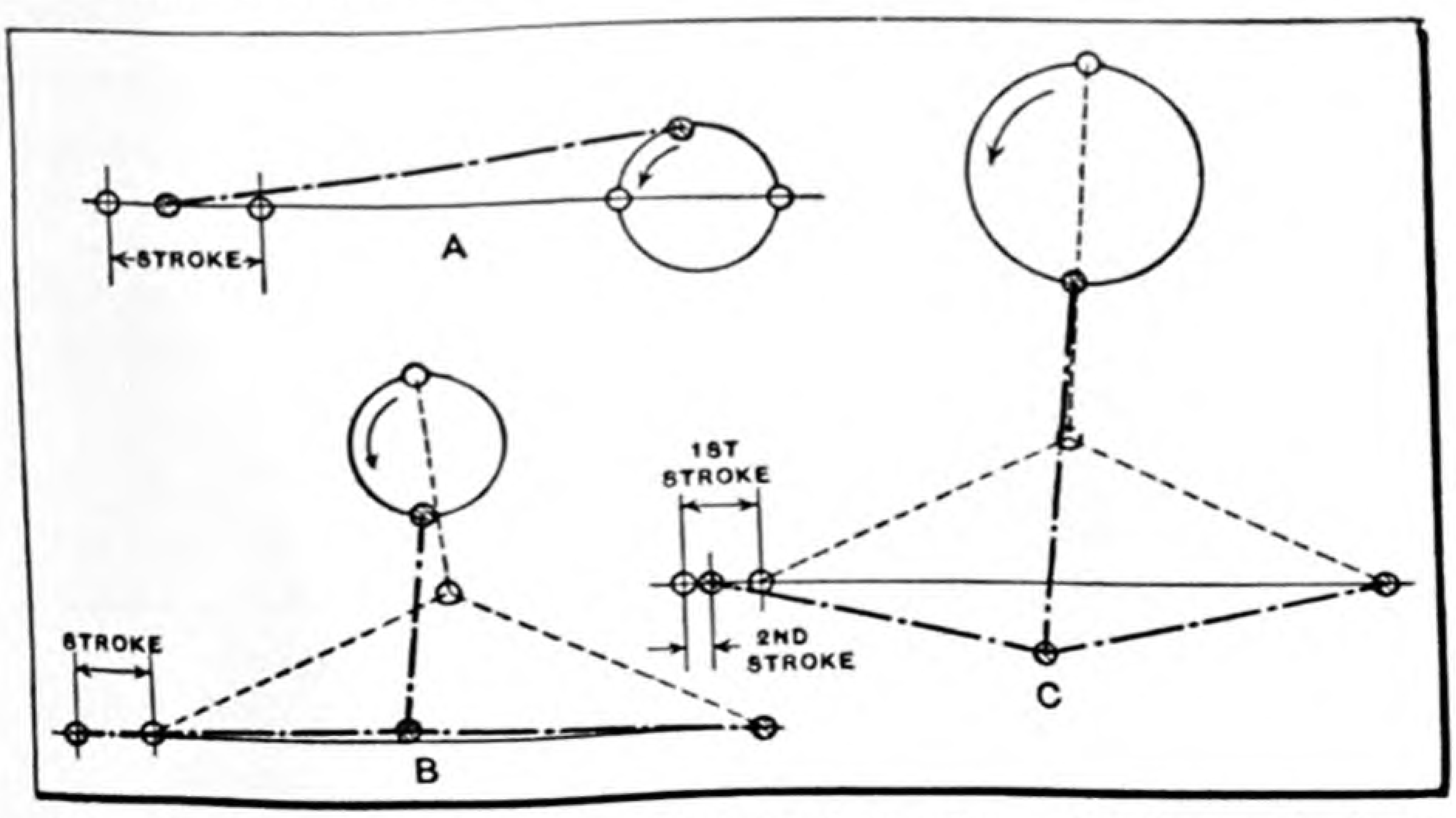
In all cold-heading operations the blank is confined at the bottom and sides, leaving the metal which is to comprise the head projecting, so that it may be upset and shaped by the punch of the heading machine. In cold-heading, the fundamental point to be remembered is that, under pressure, the wire stock will always flow in the direction of the least resistance. Cold-heading by machinery was first introduced in England, about 1760, when two brothers, John and William Wyatt, designed and built a machine for heading wood-screw blanks. In America, Josiah Gilbert Pierson's cold-

header, patented March 23, 1794, was the first machine of its kind, although the patents were destroyed when the patent office was burned early in the last century.



Miscellaneous Examples of Cold-heading

COLD-HEADERS. The design of cold-heading machines is based upon two distinct principles for reciprocating the movable ram of a cold-header: The crank principle, and the toggle principle. The crank principle is employed on most single-stroke machines and by at least one manufacturer for double-stroke machines as well. On double-stroke cold-headers of the



(A) Crank-header Diagram. (B) Two-cycle Toggle-header. (C) One-cycle Toggle-header

crank-operated type (see illustration *A*), the crankshaft must make two revolutions in order to secure the two strokes, and these two strokes will be

of equal length. The blow secured by the crank-operated header is of a quick punching character rather than a gradual squeezing operation, and exponents of crank-operated headers consider this feature to be of great importance.

The common type of toggle action is that shown at *B*; the toggle is straightened by a crank-actuated link which brings the arms of the toggle to a straight line once during each revolution of the crankshaft. This gives one stroke of the ram to each revolution of the crankshaft, but a gradual squeezing movement is obtained, especially at the ends of the stroke where the greatest amount of work is done. This type of toggle mechanism is known as the " two-cycle " type, two revolutions of the crankshaft being necessary to complete a " two-blow " rivet. Another type of toggle-operating mechanism which is extensively used on the double-stroke machines is shown at *C*; as will be seen, two blows are struck at each revolution of the crankshaft which operates the arms of the toggle. As this type of machine makes a two-blow rivet in one revolution, it is termed a " one-cycle " machine. The chief difference between the two-cycle type of toggle and the one-cycle type lies in the fact that in the two-cycle mechanism the toggle is straightened when the extreme of the crank motion is reached, but in the one-cycle mechanism, it is straightened and then pushed beyond the central position by the crank, so that in the latter machine two blows are secured during one revolution of the crankshaft.

Many heading jobs require two distinct operations to perform the work, usually on account of the shape of the pieces. For this purpose, the work is carried as far as possible with an ordinary single- or double-stroke header, after which the pieces are annealed and completed in a reheader. For handling work in which the length of the pieces under the head exceeds nine or ten diameters of the wire, it is necessary to employ dies which open longitudinally to make ejection of the work possible.

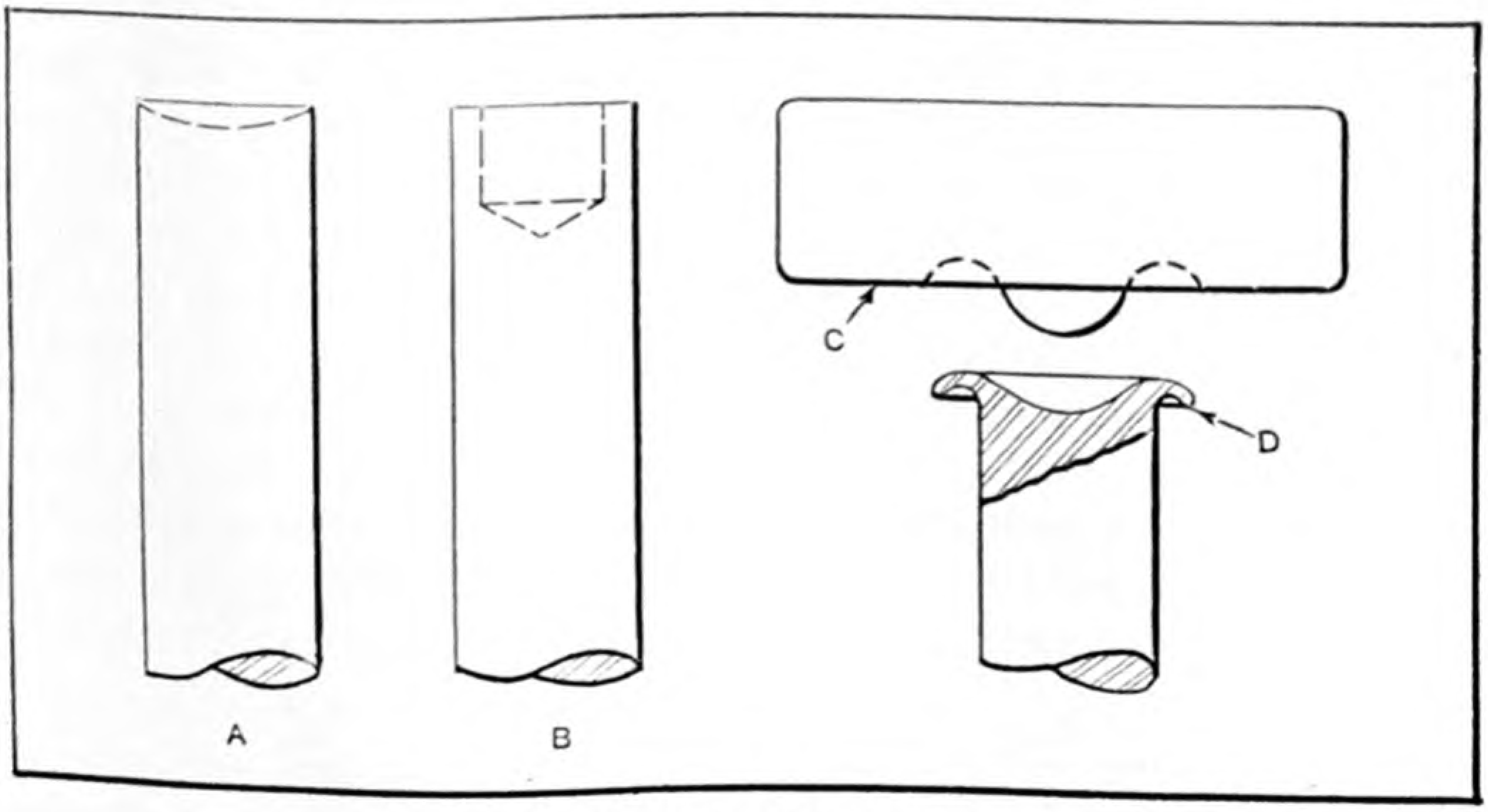
COLD-PRESSED CASTINGS. Castings of brass, bronze, aluminum and various alloys, as well as some steel and malleable castings, may be finished by a cold sizing or pressing operation in a powerful press equipped with dies shaped to suit the work. This general process may be for accurate sizing or it may be utilized in preparing some classes of hardware castings for plating, as the surface of a casting can be pressed smooth enough to eliminate or greatly reduce preparatory hand work and buffing. The pressure for such work is liable to be approximately 90 tons per square inch of projected area.

COLD-PRESSED FORGINGS. The bosses and angular or flat surfaces, etc., on many of the smaller classes of drop forgings may be finished to size within a plus and minus tolerance of about 0.001 inch, by a cold-pressing or cold-sizing process. A powerful press such as the knuckle joint type, is used

in conjunction with dies shaped to suit the shape of the boss or other part of the forging, and the working pressure may be as high as 100 tons per square inch or even higher. The object of this cold-finishing or squeezing method of sizing forgings is to obtain accuracy of form and size quickly and without milling or grinding operations.

The usual finish allowance for work of this character is $\frac{1}{32}$ inch and in some cases $\frac{1}{16}$ inch. More can be allowed, but is not required. It may be pointed out that if the rough forgings vary considerably, the pressure which the press is required to exert will also vary considerably. Accordingly, if the press is not heavy and of rigid construction, it will spring in proportion to the load, giving a possible variation beyond the tolerance. It is best to figure the pressure requirement for sizing work (close tolerance, small compression, free flow) at about 60 to 80 tons per square inch of surface to be squeezed; 400-, 600-, and 800-ton capacity presses seem to have proved the most satisfactory for the general run of automobile forgings.

COLD RIVETS. In the manufacture of electrical apparatus, particularly, it is common practice to use "cold rivets" which instead of having heads, are cupped out on the ends to permit upsetting sufficiently to form a small flange or head. The type of cold rivet usually employed in the manufacture of laminated iron pole-pieces for electrical apparatus is shown at *A* in the accompanying illustration. These rivets are made slightly concave at each



Cold Rivet Head Formation

end so that they may be readily headed by a pneumatic hammer. Five or six rivets are needed, as a rule, for each pole-piece, and from 100 to 200 blows of the pneumatic hammer are required to head each rivet properly, the number of blows depending on the size of the rivet. This is a slow process, and the cost of replacing worn and broken parts of the pneumatic hammer is

considerable. At *B* is shown a rivet with a drilled hole at each end. The holes are drilled about $\frac{1}{4}$ inch deep and of such diameter as to leave a wall from $\frac{1}{16}$ to $\frac{5}{32}$ inch thick, depending on the size of the rivet. Rivets of this design can readily be upset on both ends at one operation in a hydraulic press by equipping the upper and lower dies with hardened steel buttons like that shown at *C*. The shape of the head after compressing is shown at *D*.

COLD-ROLLED SHEET STEEL. Cold-rolled steel possesses several advantages which cannot be secured with metal that is rolled hot. Most important of these is that rolling the metal cold enables it to be given a so-called " bright " finish, there being no oxide scale or stains on the surface. When the steel is rolled hot, the hot metal is easily attacked by the oxygen of the air, which results in forming the scale with which heated metal is covered. This oxide scale is hard and it exerts a very harmful effect on the dies used for working sheet metals. For this reason, cold-rolled steel is extensively used in the manufacture of various pressed steel products. The possibility of rolling steel without forming any scale has another important advantage, in that sheet metal produced in this way can be rolled very thin, the limit being about 0.003 inch; evidently this would be impossible if the metal were at a red heat, because the production of scale would cause considerable variation in the gage of the metal, and would destroy very thin sheets.

Mills engaged in the manufacture of cold-rolled steel secure their raw material in the form of ribbon stock which is considerably thicker than the cold-rolled steel to be produced. The treatment of this material in the early stages of the process differs according to the carbon content. For steel which does not contain over 0.30 per cent of carbon, it is unnecessary to conduct a preliminary annealing process, but steel with more than 0.30 per cent of carbon must be annealed before rolling. The amount of reduction which can be obtained for each pass through the rolling mills depends upon the analysis of the steel; with low-carbon steel, the reduction may be as great as 0.022 inch for each pass, and this reduction will be gradually reduced until the final pass will only reduce the thickness of the metal about 0.005 inch. In the case of high-carbon stock, the reduction at each pass through the mill is much less.

COLD-ROLLING. The cold-rolling of shafting or bar stock consists in passing the shaft or bar through burnishing rolls which leave a smooth dense surface. Most shafts and bars, however, which are designated as " cold-rolled," have been finished by a cold-drawing process which involves pulling the stock through dies. See Cold-drawing.

COLD-SAW CUTTING-OFF MACHINES. Cold-saw machines which utilize a revolving saw are built in many different designs which differ

principally in regard to the methods of driving the saw and giving it a feeding movement relative to the work. The saw is usually mounted on an arbor, which is rotated either through spur gearing, worm gearing, a combination of spur and worm gearing, or by the direct action of a sprocket engaging either the saw teeth or radial slots formed in the saw. A general method of feeding the saw is by means of a carriage or saddle which carries the saw and its driving mechanism, and is moved along the bed by a feed-screw. Some machines are so arranged that the saw is given a swinging movement for feeding it, by mounting the saw upon an arm which is pivoted and connected with suitable feeding mechanism, which may be in the form of worm gearing, a pinion meshing with a segment gear on the arm, or a gear-driven screw connected with the arm.

Duplex Cold Saw. — The Duplex type of cold saw consists of two machines mounted upon the same bed so that the distance between the saws may be varied. Machines of this type are used for cutting off the ends of axles, crankshafts, etc., to given lengths, and also for sawing crankshafts in order to form the crank or web from a solid forging.

Multiple Cold Saw. — The multiple cold saw cutting-off machine is used for cutting long bars into a number of short lengths. One machine of this type is equipped with six heads each having a saw which operates independently. The saws feed forward and return automatically. These machines are usually designed and built to suit special classes of work.

Cold Saw of Vertical Type. — Some cutting-off machines have a vertical spindle and a saw which revolves in a horizontal plane. One design which is especially adapted for cutting off gates and risers from cast-steel gears, and other similar work, has a circular work table which is arranged very much like the table of an ordinary slotting machine. Another type of cold saw which is designed along vertical lines has a vertical column on the face of which is a saddle carrying a horizontal saw arbor, the saw in this case being in a vertical plane. The vertical column may be fed horizontally along the main base of the machine and the saddle may also be given a vertical feeding movement on the face of the column. A machine of this type is especially adapted for sawing armor plate.

COLD SHUTS. A cold shut is caused by the imperfect uniting of two or more streams of molten iron flowing together, which are too cold to coalesce. Such a fault often occurs on the upper side of a thin cylinder cast horizontally, when the iron is not sufficiently hot at the instant of pouring. It appears as a seam in the side of the cylinder, and it is very apparent that the metal has united imperfectly. Such a defect will cause the casting to split if subjected to any great stress, and it will leak under pressure. This imperfection is generally due to thinness of the metal or to improper gating. If the iron

flows in thin streams for comparatively long distances, it will be cooled very much, and probably the advancing face will be partially solidified.

COLD TEST OF OIL. The cold test of an oil is to determine the lowest temperature at which the oil will pour. A low cold test is desirable in cold weather to insure proper circulation and handling; furthermore, a low cold test for motor oils indicates the absence of heavy elements that produce carbon in the cylinders. The effect of decrease in temperature upon lubricating oils is not the same as on fluids such as water, glycerin, etc., which have fixed freezing points. Lubricating oils, which contain elements having different melting points, often deposit some of these elements before the entire mixture solidifies; consequently, the "cold test" or setting point of an oil may represent the temperature at which the solid matter begins to separate, or it may be the temperature at which the oil loses its fluidity. The setting point of a Scotch mineral oil is the temperature at which the solid paraffin begins to separate. Some pale American oils of high viscosity, Russian oils, and all dark opaque oils, which either deposit no paraffin or in which the separation cannot be seen, are considered to have reached the setting point when they cease to flow.

COLD-TWISTING. Cold-twisting is the term applied to a process for producing bars for reinforced concrete construction. The cold-twisting increases the elastic limit and produces a bar which has a more intimate bond with the concrete and greater reinforcing effect.

COLECO METAL. The bearing metal known as *coleco metal* is a lead-tin-antimony alloy, also containing a small percentage of copper. One composition specifies 77 per cent of lead, 14 per cent of antimony, 8 per cent of tin, and 1 per cent of copper.

COLLAPSIBLE TAPS. See Taps, Collapsible.

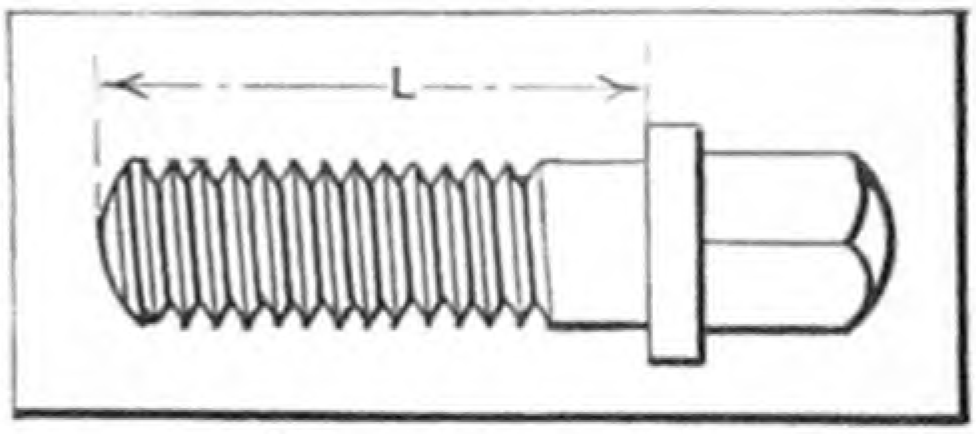
COLLAPSIBLE TUBES. Collapsible tubes, such as are commonly used for artists' colors, tooth paste, etc., are usually manufactured by the cold extrusion process. The metal from which these tubes are made is of either tin or lead composition and there is a large variety of alloys suitable for this class of work. These tubes are also often made from pure tin, and such tubes are considered superior to those made from the various compositions. The tubes are extruded from blanks of disk or special shapes.

An alloy which will be found suitable for both collapsible tubes and soft metal bottle tops, consists of 4 ounces copper, 6 ounces antimony and 16 ounces tin, melted together, the resulting alloy being used with varying quantities of pig tin. For collapsible tubes 50 ounces of the alloy and 200 pounds of pig tin are used; for bottle tops, 134 ounces of the alloy and 200 pounds of pig tin. Any one of the three following compositions may also

be used successfully in the manufacture of collapsible tubes: (1) antimony 14 per cent and tin 86 per cent; (2) antimony 5 per cent and tin 95 per cent; (3) copper 2 per cent and tin 98 per cent.

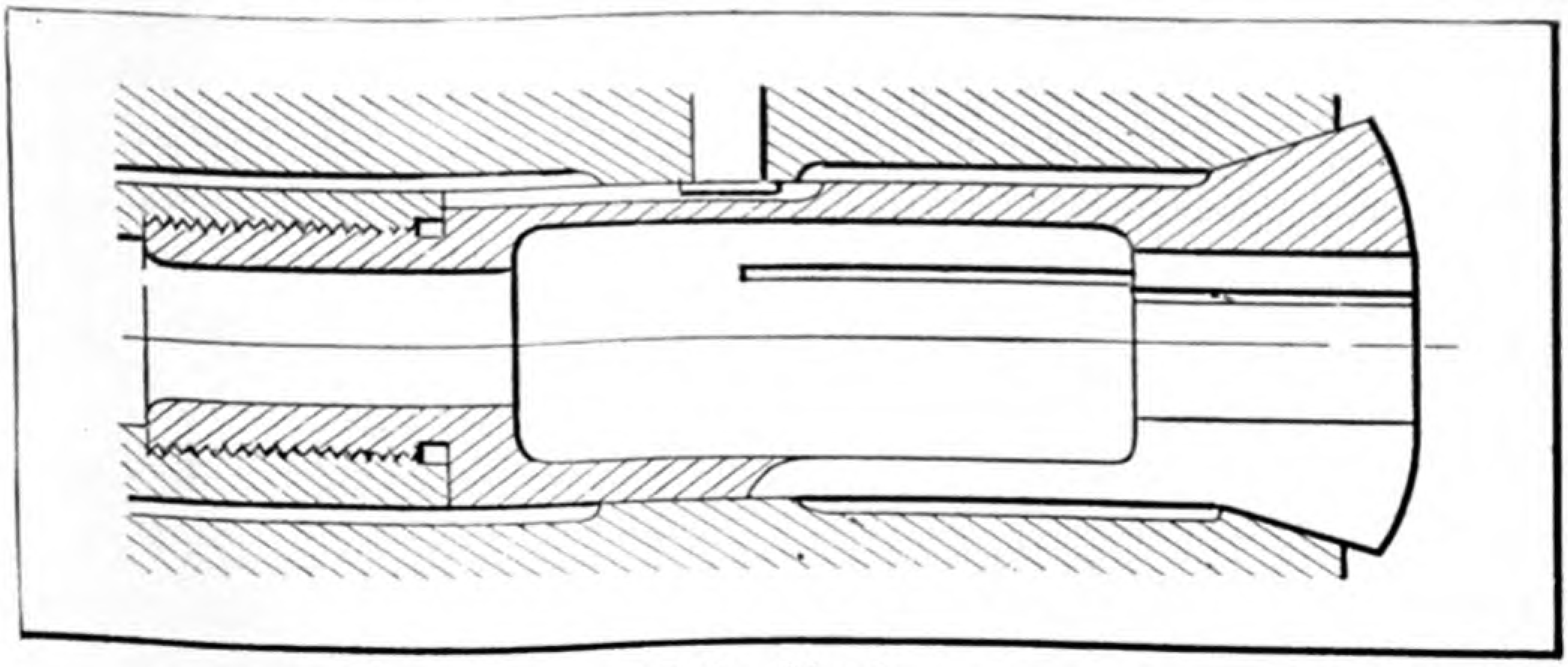
Collapsible tubes are now being produced successfully from aluminum. The annealing process for restoring the ductility of the metal after extrusion is an important part of this development.

COLLAR-HEAD SCREWS. Collar-head screws are used on finished work, or on rough work which has been spot-faced to provide a bearing for the collar or enlarged part of the head. Screws of the collar-head form are also commonly used in toolposts or toolholders of various kinds; the particular advantage is that the collar prevents a wrench from slipping down below the head, thus causing inconvenience in making adjustments. Dimension *L* (see illustration) represents the nominal length of the screw.



Collar-head Screw

COLLET CHUCK. The collet type of chuck consists of a split sleeve or collet which has a tapering or conical end that fits into a seat of corresponding taper so that a lengthwise movement of the collet causes a contraction or expansion of the gripping surfaces (see illustration). The collet type of


Collet Chuck

chuck is the most convenient form for gripping pieces that are long in relation to their diameter, such as bar stock, etc. Collet chucks are extensively used on bench lathes, turret lathes (when operating on bar stock), and on turning machines of the automatic screw machine class.

Some collet chucks are closed by a backward pull and others by a forward push, the movement for closing depending upon the inclination of the taper.

COLLOIDAL FUEL. A mixture of fuel oil and pure coal is known as colloidal fuel. The usual amount of coal is about 40 per cent by weight,

with possibly 1 per cent of some emulsifying agent. The oil may have suspended in it, however, as much as 65 per cent of coal by weight and yet be sufficiently fluid to permit pumping or atomization. The object is to combine with the oil low-grade coals of the high fixed carbon or high ash types which cannot be burned successfully in the usual manner. Colloidal fuel has a heating value per pound varying from 14,500 to 17,000 British thermal units, a weight of 8.3 to 11 pounds per gallon, and for equal volumes it has nearly twice the power value of coal, and nearly 10 per cent more than fuel oil. It can be covered with water and sinks in water, thus reducing the fire hazard.

COLORING METALS. See kind of metal or finish: Brass Coloring; Copper Coloring; Cyanide Coloring of Steel; Flemish Finish on Brass; Heat-black Finish; Silver Finish on Brass; Steel Coloring.

COLORING POLISHED PARTS. The term "coloring," as used in the metal finishing trade in connection with polishing or buffing, refers to the operation whereby a very fine finish is obtained. Chisels, hammers, screwdrivers, wrenches, and similar classes of work which are to be highly finished, but not plated, usually require four operations which are: roughing, dry-fining, greasing and coloring. That is, by means of four operations all the finishing work is done on polishing wheels, including the roughing which is frequently regarded as a solid grinding wheel job. Sometimes there are two steps to the greasing operation — rough and fine greasing. For some hardware, typical of which are cheaper screw-drivers and wrenches that do not demand a high finish, two operations are sufficient — roughing and dry-fining. The coloring operation may follow plating in order to give the plated surfaces a luster.

COLUMBIUM. A metallic element the chemical symbol of which is either Cb or Nb; the atomic weight 93.5; the specific gravity about 7; and the melting point 2200 degrees C. (about 4000 degrees F.). It is also known as *niobium*.

COLUMN. In engineering, a column is a structural member which has considerable length in proportion to its width, depth, or diameter, so that failure in compression is most likely to occur by the effect of bending stresses rather than by crushing. Generally, a structural member subjected to compression is known as a column, strut, or post if its length exceeds from six to ten times its width, depth, or diameter.

COLUMN FORMULAS. See Rankine's Formulas.

COMBINATION CHUCKS. The combination type of chuck is so arranged that the jaws may be adjusted either independently or universally. There are two common methods of obtaining this change of adjustment.

In the design having geared screws operated by a circular rack or gear, the latter is so arranged that it may be dropped out of mesh with the screw pinions, so that each screw may be turned independently. With a scroll type of combination chuck, all of the jaws may be moved together by rotating a spiral scroll or they may be adjusted independently by turning screws that are located between the jaws and the scroll.

COMBINATION GRINDING WHEEL. When a wheel is made up of abrasive grains of different sizes or numbers, it is known as a combination wheel. The coarser grains are effective in taking roughing cuts, but the wheel is sufficiently compact to obtain a fine finish if properly used. Such wheels are extensively employed.

COMBINED CARBON. This is the form in which carbon is present in white cast iron, the carbon being in chemical combination with iron as cementite or carbide of iron, (Fe_3C). The combined carbon is the principal factor in determining the hardness, strength, and soundness of castings.

COMBUSTION. Chemically considered, combustion is the chemical union of oxygen with other elements and compounds at a rapid rate — usually so rapid that heat and flame are produced. When combustion is extremely rapid, it is termed an "explosion."

The combustion of a fuel requires three stages: 1. The absorption of heat to raise its temperature to the point of ignition. 2. The distillation and burning of the volatile gases. 3. The combustion of the fixed carbon. When fresh fuel is added to the fire, it absorbs heat until its temperature reaches the point at which the combustible elements will unite with the oxygen of the air. This point varies with the kind of fuel, commonly running from 600 to 800 degrees F. in the case of lump coal and coke. Carbon monoxide requires a temperature of 1210 degrees F., and hydrogen, 1100 degrees F. While the coal is being raised to the point of ignition, the so-called "hydrocarbons," such as marsh gas, tar, pitch, naphtha, etc., are driven off in the form of a gas and combine with the oxygen of the air which is supplied through the bed of the hot fuel. When the hydrocarbons have been driven off, combustion of the solid portion of the fuel, that is, the carbon, takes place. This unites with the oxygen of the air to form carbon monoxide and carbon dioxide. Any substances which are not combustible remain in the form of ash and clinker.

Air Required for Combustion. — The theoretical amount of air required for the combustion of various fuels, in pounds per pound of fuel, based on typical analyses of each is as follows: Coke, 10.8; anthracite, 11.7; bituminous coal, 11.6; lignite, 8.9; wood, 6.0; and oil, 14.3. In practice, due to the impurities in fuel and the difficulty in getting air into contact with all particles, it is impossible to obtain perfect combustion with the theoretical

amount of air, and an excess sometimes equal to double the theoretical amount is required. Usually, however, about 50 per cent excess air is sufficient to meet the requirements. This excess air is required because ideal conditions for combustion cannot be attained in actual practice, owing to the difficulty in supplying air to all parts of the fire uniformly. This results in some of the fuel receiving less oxygen than is necessary for complete combustion, while other parts have a surplus. On the other hand, if too much air is supplied and insufficient time is allowed after the gases have become incandescent, before they come in contact with the cooler plates of the boiler, combustion will also be retarded.

COMBUSTION ELEMENTS IN FUELS. The elements contained in the usual forms of fuel, which enter into the process of combustion, are oxygen, carbon, hydrogen, and sulphur. There are various other constituents present which have no fuel value, such as the iron, silicon, etc., found in coal. These usually exist in small quantities, and are classed as impurities. They produce a certain waste in the form of ash, and, in addition to this, their temperature must be raised to that of the fire before becoming separated from the other elements, and more or less of this heat is lost as they are discharged from the fire.

Oxygen is the universal element of combustion; it is an invisible gas and makes up about one-fifth the volume of the air in an uncombined state. It is usually present in coal in amounts varying from 1 to 25 per cent, according to the grade. *Carbon* is a solid, and is found in a pure state in the form of graphite and charcoal. It is the principal heat-producing element in coal and other fuels, including liquids and gases. *Hydrogen* is a combustible gas, and exists in nature only in combination with some other element.

Nitrogen is an invisible gas, forming about four-fifths the volume of the atmosphere. It does not unite chemically with the other constituents of the air or take any part in the process of combustion. For this reason it is a source of loss in the operation of a steam boiler, because, in order to supply the necessary oxygen for combustion, four times the volume of nitrogen must be raised from the temperature of the atmosphere to the point of combustion, and then discharged at a high temperature with the waste gases into the chimney. This process adds nothing to the heat of the furnace and is constantly extracting heat from it. Nitrogen is found in coal in amounts varying from 0.5 to 2 per cent, by weight. *Sulphur* enters into the composition of coal in amounts varying from 0.5 to 5 per cent. Although sulphur is combustible, the amount of heat given off is small, and the gases are so detrimental to the boiler plates that it is commonly considered an impurity.

COMBUSTION OF COAL. Combustion of coal involves the rapid chemical union of oxygen with carbon, hydrogen, and sulphur (and other

elements) accompanied by a diffusion of heat and light. Perfect combustion occurs when the combustible unites with the greatest possible amount of oxygen, but without excess. Imperfect combustion occurs when the union between the combustible and oxygen is incomplete, or when an excess of oxygen is present. The principal combustibles in fuels are carbon, hydrogen, and sulphur. Carbon is the most abundant. Hydrogen is usually found in combination with carbon in the form of hydrocarbons. Sulphur is found in most coals. It usually occurs either as a sulphide of iron or a sulphate of lime.

Each combustible element will unite with oxygen in certain definite proportions and will generate a definite amount of heat which is termed the *calorific value* of the substance. Some calorific values of elementary combustion are given below. Carbon to carbon dioxide, 14,600 B.T.U.; carbon to carbon monoxide, 4450 B.T.U.; carbon monoxide to carbon dioxide, 10,150 B.T.U.; hydrogen to water, 62,000 B.T.U.; methane CH_4 to carbon dioxide and water, 23,550 B.T.U.; sulphur to sulphur dioxide, 4050 B.T.U. Thus, when one pound of carbon is burned to carbon dioxide, sufficient heat is generated to raise 14,600 pounds of water one degree, or one-half of this amount of water two degrees.

COMBUSTION, SPONTANEOUS. See Spontaneous Combustion.

COMBUSTION, SURFACE. See Surface Combustion.

COMMUTATING POLES. Small narrow poles placed between the main poles of direct-current machines for preventing sparking between one of the edges of the brushes and the commutator. The commutating poles are wound in series with the armature winding, the number of turns being such that their magnetomotive force exceeds the armature magnetomotive force by an amount which maintains, under the commutating pole, sufficient flux for the reversal of the current in the coils that are short-circuited by the brushes.

COMMUTATION. An armature coil of an electrical machine is said to undergo *commutation* when it is short-circuited by the brushes and the current in the coil is reversed from its full value in one direction to an equal value in the opposite direction; that is, when a pulsating current is rectified to direct current.

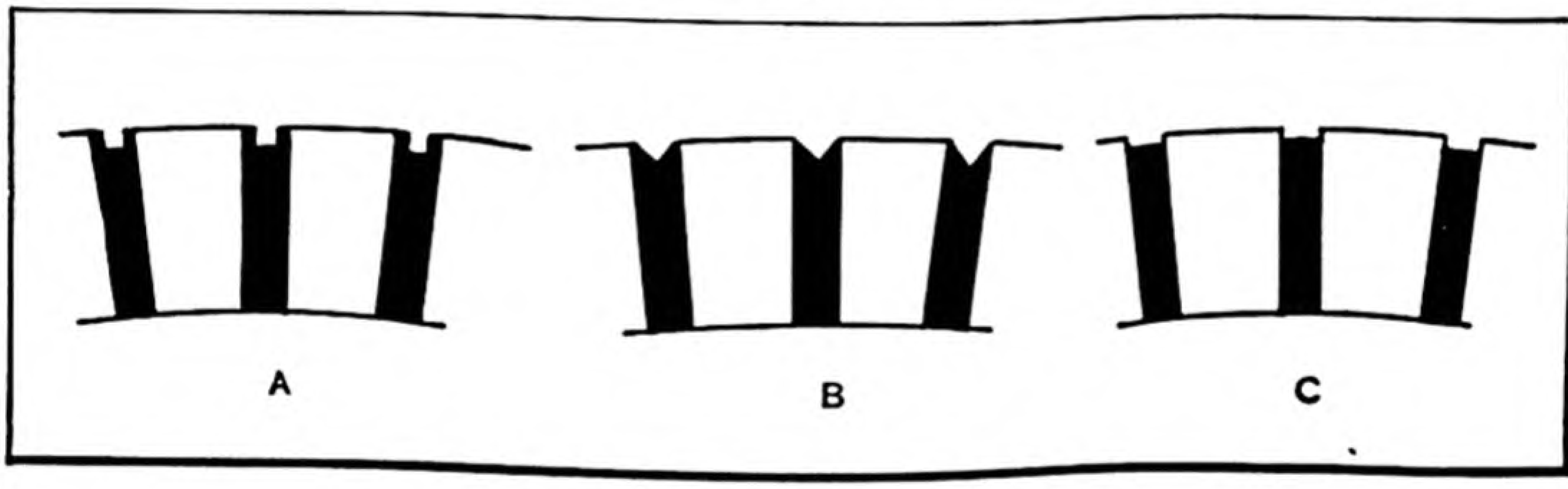
COMMUTATOR. See Armature, Motor; also Generators, Direct-current.

COMMUTATOR CONTROLLER. A hand-operated electric motor controller of the non-automatic type used as a reversing controller. It is similar in construction to the drum controller, except that in the commutator controller the fingers revolve instead of the drum. This controller is limited

in size to approximately from 100 to 150 horsepower, but is mechanically strong and simple to operate and can be provided with brushes that make it very durable in heavy service. See also Drum Controller.

COMMUTATOR INSULATION. The mica insulation between the copper commutator segments is usually more resistant to the wear of the brushes than the segments. This results in the copper wearing off and leaving the mica projecting, a condition termed "high mica." Pure amber mica, which has about the same wearing qualities as the copper used in commutator segments, was formerly used, but it is very expensive and difficult to obtain. The mica used consists of built-up sheets made from plates or lamellae 0.002 to 0.004 inch thick of both amber mica and the harder, white kind of mica stuck together with some gum or resin. Both the white mica and the baked binder are harder and more resistant to wear than the copper commutator segments.

In order to prevent the "high mica" condition, the mica is generally grooved or under-cut between the segments as shown at *A*, and *B*. The



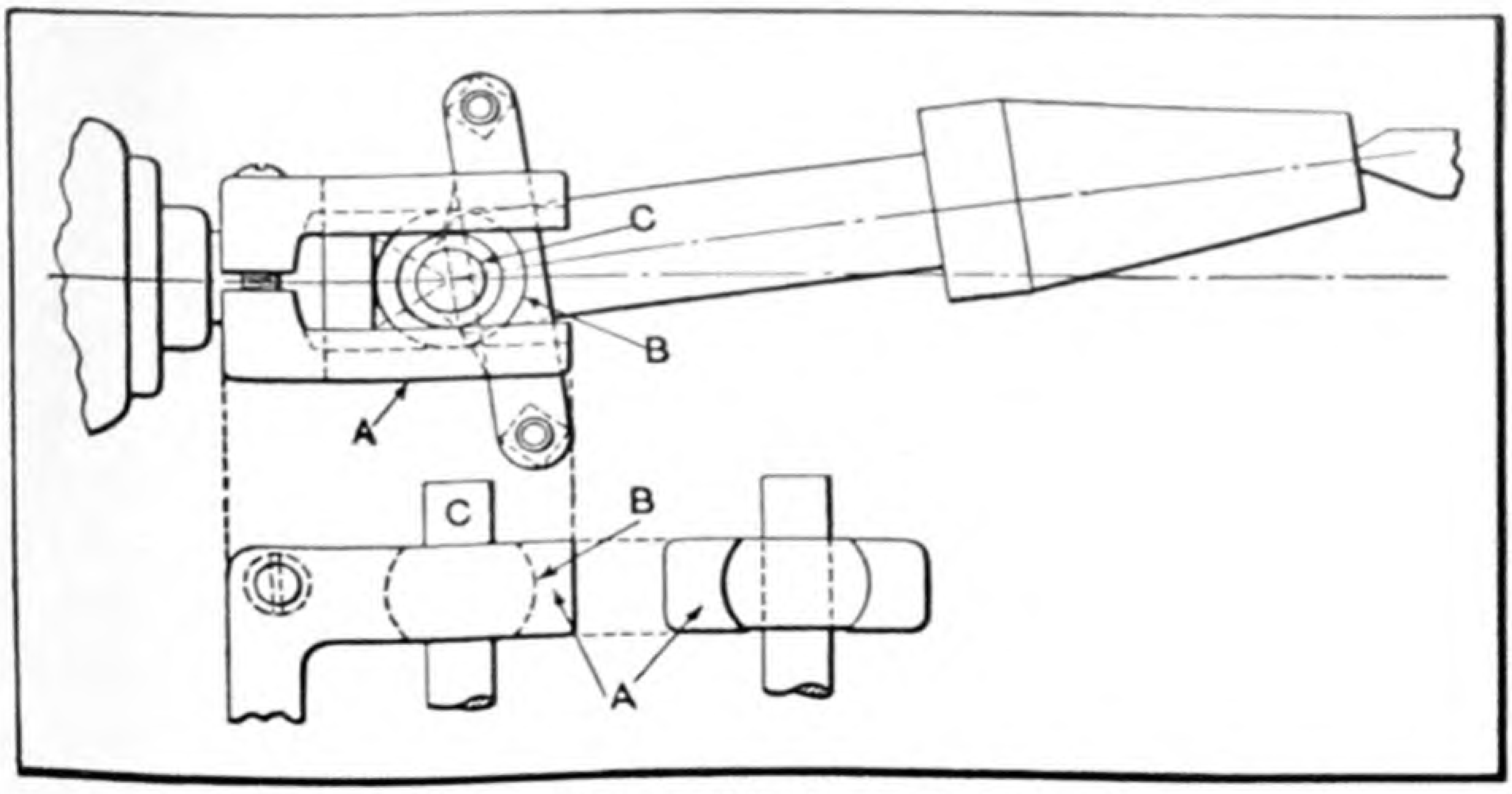
Commutator Mica Insulation

style of under-cut as shown at *A* has been considered the better, although its superiority, if any, is not pronounced. The condition shown at *C* should be avoided, especially in the case of large, slow-speed machines, or machines operating in places where dust of a current-conducting nature is prevalent. The entire brush contact area should be grooved without having the grooves run out on the end of the commutator. Ordinarily, the grooves should be about $\frac{1}{32}$ inch deep.

COMMUTATOR MOTORS. The rotating member of alternating-current commutator motors is called the *armature* and consists of a shaft, spider, laminations, windings and commutator, the same as a direct-current commutator motor. The stationary member is called the *field* and is constructed along the same lines as the field of the direct-current motor, except that its magnetic circuit is made up of laminations instead of depending upon a cast frame, and usually cast poles, for part of the magnetic path. The field winding in single-phase motors is usually a concentrated or massed winding;

but instead of being placed on poles which are separated by a considerable distance as in the direct-current motor, it is placed in large slots in the laminations. Polyphase commutator motors differ from the single-phase motor construction mainly in the arrangement and connection of the field and compensating windings and in the arrangement of the brushes.

COMPENSATING DOG. A compensating dog or driver is a type designed to prevent the inaccuracy in spacing which often results when indexing taper work. If the axis of the work is not in alignment with the axis of the dividing-head spindle, and an ordinary driver is used, the spaces will vary somewhat, especially if the work is held at a considerable angle. A form of compensating driver which practically eliminates this error has a forked arm *A* (see illustration) which is secured to the dividing-head spindle. This arm is engaged by a ball-shaped part *B* mounted on the cylindrical end *C* of the driver. The latter is clamped in such a position that the



Compensating Dog to Eliminate Indexing Errors

center of the cylindrical driving end is approximately in line with the end of the work, as shown by the plan view. The ball fits closely between the curved surfaces of the forked arm and adjusts itself as the relation between the driver and arm change owing to the angularity between the axes of the work and the index spindle. The forked arm can be adjusted to take up all play between the ball and the curved surfaces between which the ball is held. As the driving is done at a point opposite the end of the work, the irregularity of the indexing movement is very slight and negligible for ordinary milling or fluting operations; moreover, there is no binding action between the dog and driver plate, such as may occur with the ordinary dog, having a tapering driving end.

COMPENSATORS. Compensators for line drop are devices used to modify the reading of electric power station voltmeters, without the use

of pressure wire from the distributing point, so that the reading corresponds to the pressure at that point. *Balances* are sometimes called compensators or direct-current compensators.

COMPLEMENT OF ANGLE. The complement of a given angle (a) equals $90° - a$; hence if the angle a exceeds 90 degrees, its complement is negative. The complement angle of a 60-degree angle equals $90 - 60 = 30$ degrees.

COMPOSITE GEAR TOOTH SYSTEM. See Gear Tooth Standard, American.

COMPOSITION OF FORCES. The expression "composition of forces" relates to the finding of the resultant of two or more forces. See Force.

COMPOUND. In chemistry, a compound is a substance consisting of chemically united atoms of two or more elements. For example, sulphuric acid which consists of hydrogen, sulphur, and oxygen is a chemical compound. Substances which can be decomposed into simpler ones are known as compounds; those which cannot be decomposed into anything simpler are known as *elements*.

A substance is a mechanical mixture or a chemical compound, according as the elements composing it lose or retain their identity. If chlorine and hydrogen are mixed in any proportion, the chlorine in the mixture may be evident by its characteristic color and odor, showing that the combination is only a mechanical mixture. If, however, this mixture is exposed to a strong light, a new compound is formed in which the chlorine cannot be detected either by any odor or color, nor can it be separated except by chemical means; this combination, known as hydrochloric acid, is a chemical compound. The gases, however, will combine only in exactly equal volumes, so that if there is any excess of either element present that part will remain uncombined. This fact is true in all cases, as a chemical compound differs from a mechanical mixture in that each element of the chemical compound has a certain fixed and unvariable combining proportion, which is its valence; whereas, a mechanical mixture of substances can be made with varying amounts of each ingredient. In a mechanical mixture, the particles of each ingredient can usually be identified and separated by mechanical means, but, in a chemical combination, each component is so blended that its identity is lost.

COMPOUND DIES. Compound dies differ from plain blanking and follow dies in that the simple punch and die elements are not separated but are combined so that both the upper and lower members contain what corresponds to a punch and die, as well as suitable stripper plates or ejectors. The faces of the punches, dies, and stripper plates are normally held at about

the same level and the strippers are spring supported so as to recede when the stock is being cut. A compound die produces more accurate work than the types previously referred to for the reason that all operations are carried out simultaneously at one stroke, while the stock is firmly held between the spring-supported stripper plates and opposing die-faces. Such delicate parts as armed wheels or gear punchings for clocks, meters, etc., are examples of the work that can be done in this form of die. Such parts are made complete, including the arm spaces, center-hole, and holes in the arms or rim, if desired, during one stroke of the press.

COMPOUND INDEXING. See Indexing.

COMPOUND LEVERS. It is sometimes necessary to use two or more levers connected one to the other in a series, where it would not be convenient to obtain the desired multiplication with a single lever, or where it is necessary to distribute the forces acting. In such cases, the levers are called *compound* levers, and their application is found in testing machines, car brakes, printing presses, and especially in weighing scales.

COMPOUND REST. The compound rest of a lathe is an upper slide mounted on the lower or main cross-slide. It can be turned to any angular position so that the tool, which ordinarily is moved either lengthwise or crosswise of the bed, can be fed at an angle. The base of the compound rest is graduated in degrees and the position of these graduations shows to what angle the upper slide is set. It is also known as a Compound Slide.

COMPOUND STRESSES. Stresses acting in two or three directions at the same time are called "compound stresses." An example is found in a long thin cylinder closed at each end and subjected to internal fluid pressure. There is a tangential stress which tends to burst the cylinder along a line parallel with the axis, as well as a longitudinal stress, due to pressure on the heads, which tends to tear the cylinder apart in a plane perpendicular to the axis; that is, a small square in the wall of the cylinder is subjected to stress in two directions, each at right angles to the other. Similar examples are found in stresses due to combined bending and twisting in a shaft, stresses due to centrifugal force in a rotating wheel disk, and stresses in a hub pressed on a shaft. See Guest's Formula.

COMPOUND TOLERANCES. A compound tolerance refers to those conditions where the established tolerances on more than one dimension determine the required limits. These exist in conjunction with the dimensioning of composite surfaces or those surfaces which are required to maintain a co-relation which cannot be expressed by a single dimension.

COMPOUND-WOUND GENERATOR. A compound-wound generator (see diagram) is provided with both a series and a shunt field in order to

keep the voltage constant as the load increases. The series winding automatically increases the excitation, and thus the voltage, as the load comes on, so as to counterbalance the drop in voltage that would take place, if only a shunt winding were provided. The series coils, therefore, reinforce the shunt field in direct proportion to the increase of load and thus hold the terminal voltage constant, balancing the drop due to increased copper loss and armature reaction at the increased load. To obtain a perfect regulation, it is also customary to provide an adjustable resistance in the shunt-field circuit similar to the simple shunt-wound generator. Compound-wound generators may be so proportioned that the voltage may be held constant over a wide range in load, and are then said to be "flat-compounded." They may also be so proportioned that the series field adds enough excitation not only to maintain a constant terminal voltage, but to increase the same as the load increases, and thus compensate for the voltage drop in the supply circuit and maintain an approximately constant voltage at the point of utilization. When so designed, the generator is said to be "over-compounded."

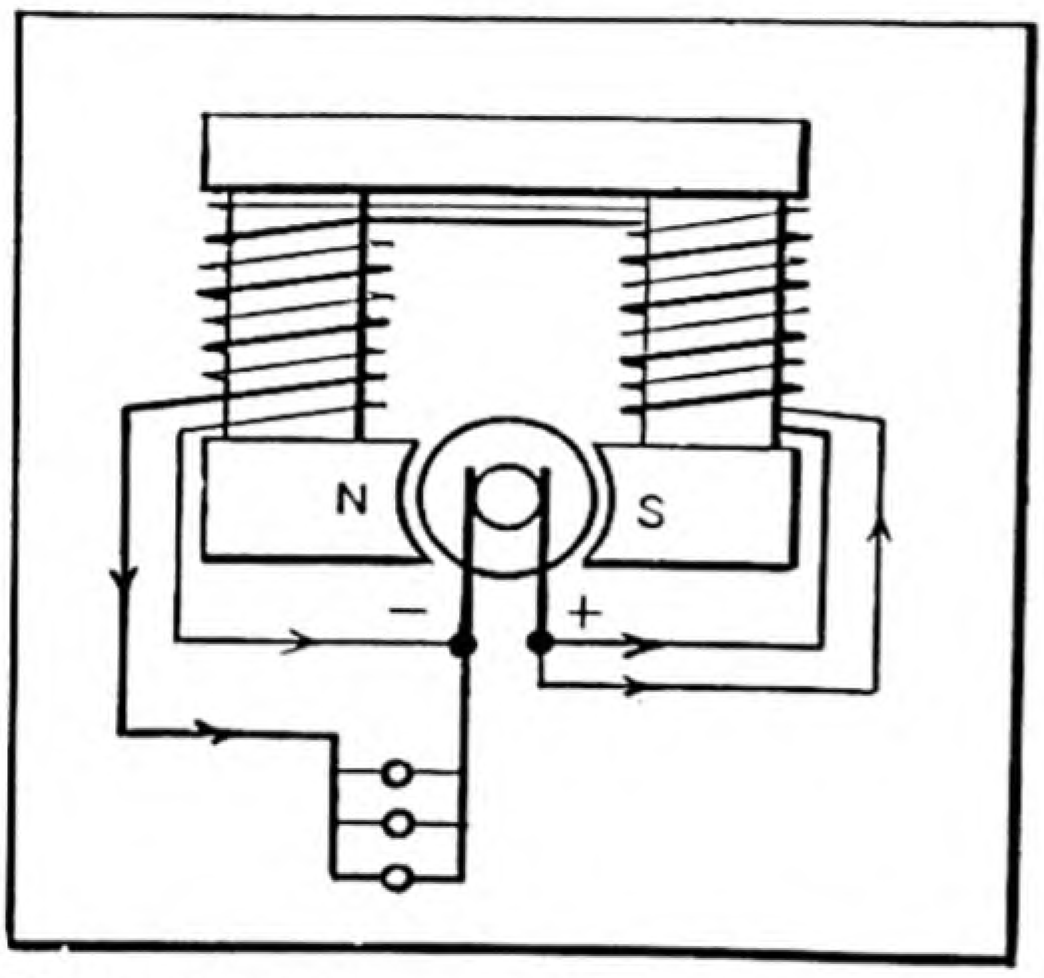


Diagram of Compound-wound Generator

COMPOUND-WOUND MOTOR. The compound-wound motor is a direct-current motor having both a shunt and a series field winding. The shunt field is connected to the main line as in a shunt motor, while the series field is in series with the armature and carries all of the current passing through it as in the series motor. The field of an average compound motor is composed of about eighty per cent of shunt winding and twenty per cent of series winding, although this proportion may be varied to suit the class of work for which the motor is to be used. The speed of a compound motor is more nearly constant than that of a series motor, but the drop in speed from no load to full load is considerably more than in a shunt motor, owing to the action of the series part of the winding. The characteristics of the compound motor partake of those of both the series and the shunt motors in about the same degree as the relative proportion of the two windings composing the field.

COMPRESSED AIR INTERCOOLERS. See Intercoolers for Compressed Air.

COMPRESSED AIR, MOISTURE IN. The atmosphere contains a certain amount of moisture or water vapor, and its capacity for moisture

increases with the temperature. When compressed, this water vapor is carried with the air through the pipes to places where the air is to be used, and, as the air is often cooled considerably during its passage through long pipe lines, the water vapor has a tendency to condense. This water due to condensation frequently causes trouble. Moisture or water cannot be entirely eliminated from service lines, but much of it may be deposited by proper cooling devices. Moisture enters the compressor in the free air and passes into the intercooler, where some of it is deposited by the sudden temperature drop there. In some machines, this deposited water is drained off, but, in others, it passes with the air into the high-pressure cylinder, and the heat of compression readily absorbs it again, passing it directly to the reservoirs. If an aftercooler (this is a nest of cold tubes of a construction exactly similar to that of the intercooler) is placed between the discharge pipe of the high-pressure cylinder and the reservoir or service lines, the temperature of the air will be suddenly reduced to normal, and most of the water will be deposited where it can be drained off easily. The idea is to insure the reduction of the temperature of the discharged air to normal before it enters the service pipes. Another way is to connect at least three reservoirs in series so that the air has to pass through all of them before entering the lines. This will collect the water very well, but it is necessary to drain the reservoirs frequently. See also Air Compression and allied subjects.

COMPRESSION. Compression in a steam engine acts in connection with the premature release in order to reduce the shock at the end of the stroke. During the forward stroke of an engine, the exhaust port in front of the piston remains open. Shortly before the end of the stroke, this closes, leaving a certain amount of steam in the cylinder. The continuation of the stroke compresses this steam, and by raising its pressure forms a cushion, which, in connection with the removal of the pressure back of the piston by release, brings the piston to a stop and causes it to reverse its direction without shock. High-speed engines require a greater amount of compression than those running at low speed.

COMPRESSION, ADIABATIC. See Adiabatic Expansion and Compression.

COMPRESSION COUPLING. A coupling provided with a split sleeve and two conical sleeves surrounding it. The sleeves are so arranged that when the two conical outside sleeves are drawn together by bolts and nuts, the inside split sleeve grips the two shafts to be coupled together and holds them firmly.

COMPRESSION, ISOTHERMAL. See Isothermal Expansion and Compression.

COMPRESSOMETER. A compressometer is an instrument which is used to determine the elastic limit of a material under compression or the deformation under fixed increments of load. It is equipped with a micrometer indicating device.

COMPRESS POLISHING WHEEL. The compress polishing wheel is a type of wheel in which the material, usually leather or canvas, is placed crosswise of the face of the wheel instead of the wheel being made up of parallel flat disks. The wheel consists of an angular ring, made up of rectangular pieces of material arranged radially and compressed to form a ring or " cushion " of polishing material one or more inches in depth. This cushion is assembled with side plates engaging annular recesses in the compressed ring. The side plates, in turn, are riveted to a hub.

CONCATENATION. A method of connecting alternating current induction motors mounted on the same shaft. The primary of one motor is connected to the secondary of the other, and either motor may be provided with one or more windings, so as to change the number of poles. The object of this winding is to obtain a method for speed regulation.

CONCRETE. Concrete consists of a mixture of sand, gravel, or broken stone and cement in various proportions. Water is added to this, which, when chemically combined with the cement, binds the whole mixture together into a solid mass having the characteristics of strong artificial stone. In proportioning the quantities of the various materials used, the object is to obtain a concrete in which the air spaces are as small as possible, and as the cement is by far the most expensive of the materials used, it is desirable to use as little of it as is consistent with strength. The amount of each ingredient is usually measured by volume, and the mixture is generally designated by stating the proportion of each ingredient in a given order, as " 1 : 2 : 5," where the first figure indicates the proportion, by volume, of cement; the second, the proportion of sand; and the third, the proportion of stone or gravel; hence, 1 : 2 : 5 concrete is a concrete containing one barrel of cement, two barrels of coarse sand, and five barrels of gravel or broken stone.

Frozen Concrete. — The freezing of concrete will not damage it, if it has first had a chance to set under favorable conditions for about two days. The effect of the freezing is simply to delay the process of hardening, which will again proceed under suitable conditions, and the concrete will eventually attain its full strength. If concrete is frozen before it has commenced to set firmly, it will not be injured, provided precautions are taken to prevent it from freezing again after it thaws until it is sufficiently hardened to withstand the effects of subsequent freezings. It is alternate freezing and thawing while setting that causes the damage. When concrete work

is done in winter, it is necessary to devise means of mixing the concrete with materials freed of frost, placing it in the forms before it has commenced to freeze, and then protecting it and keeping it warm for about two days.

CONCRETE MIXING. In making concrete, the amount of mixing water controls the strength to such an extent that strength may be predetermined simply by regulating the amount of water relative to the quantity of cement. This predetermination of concrete strengths through the use of varying amounts of water is known as the " water ratio " method. This method insures uniform strength, regardless of changes in workability or in the sizes of the aggregates. For ordinary work, the proper amount of water to use is the smallest quantity that will give a mixture of good workability. Builders in general should use as dry a mixture as practicable.

Thorough mixing is another important point. Concrete should remain in the mixer for at least a minute, and most State Highway Commissions require at least $1\frac{1}{2}$ minutes for mixing. The speed of mixing is not so important as the time, for materials must be thoroughly blended to form good concrete. Dusty or dirty sand, gravel, or crushed stone aggregates will not make strong concrete. Frequently sand and pebbles must be washed as well as screened to remove clay and organic material. Although concrete should be mixed and placed in the forms as dry as possible, it requires frequent moistening to " cure " it properly. For instance, in highway building, a new concrete road is flooded with water for from ten to fourteen days or is kept moist by a covering of damp earth or straw.

Concrete Mixing Water. — The Bureau of Standards recommends the use of a small quantity of calcium chloride in the mixing water of concrete in order to hasten the hardening of the concrete. Tests showed that the addition of calcium chloride to the mixing water up to 10 per cent by weight increases the strength from 30 to 100 per cent over that of concrete in which plain water is used, and that the best results are obtained when from 4 to 6 per cent of calcium chloride is used. While calcium chloride has no harmful effect upon the concrete, it does affect iron and steel, and therefore should not be used for reinforced concrete.

CONCRETE MIXTURES. For water tanks and similar structures subjected to considerable pressure and required to be water-tight, mixtures rich in cement and composed of either 1 : 1 : 2 or 1 : $1\frac{1}{2}$: 3 concrete are used.

For reinforced floors, beams, columns, and arches, as well as for machine foundations which are subjected to vibration, a 1 : 2 : 4 concrete is generally used. This composition is also employed when concrete is used under water.

For ordinary machine foundations, retaining walls, bridge abutments, and piers in the air, a 1 : $2\frac{1}{2}$: 5 concrete is satisfactory, and for ordinary

foundations, heavy walls, etc., a lean mixture of 1 : 3 : 6 concrete may be used.

CONCRETE POLES. Concrete poles for transmission lines are of three general types, known as solid, hollow, and trussed poles. In the United States, the majority of poles now in use are of the solid type, whereas in Europe hollow poles are used principally. Solid and hollow poles may have the same outward appearance, being either round, square, hexagonal, octagonal, or square with beveled corners. Reinforcing rods are placed near the outer surfaces, the number of rods varying with the size of pole and the load it must stand. Many square poles have only four rods, one being in each corner. Solid concrete poles have considerable flexibility and strength. A 35- or 40-foot pole fixed solidly in the ground for 6 feet of its length may be deflected from 6 to 8 inches and come back to its normal position, after removal of the load.

CONCRETE STRENGTH. The compressive strength of concrete which, after having been mixed and laid, has set twenty-eight days, varies from 1000 to 3300 pounds per square inch, according to the mixture used. If made in the proportion 1 : 3 : 6 (one part cement, three parts sand, and six parts stone or gravel, by volume), using soft limestone and sandstone, a compressive strength of only 1000 pounds per square inch may be expected, whereas a mixture of 1 : 1 : 2, made with soft limestone and sandstone, will have a strength of 2200 pounds per square inch. A mixture of 1 : 3 : 6, made from granite or trap rock, will have a compressive strength of 1400 pounds per square inch, while a mixture of 1 : 1 : 2, made from granite or trap rock, will have a strength of 3300 pounds per square inch. Other mixtures will have values between those given. Concrete may be mixed with cinders, but, in this case, very inferior strength is obtained; the richest mixtures will give a strength of only about 800 pounds per square inch.

CONDENSATION IN ENGINE CYLINDER. The principal waste of steam in steam engine operation is due to condensation during the stroke. This occurs because of the fact that during expansion and exhaust, the cylinder walls and head and the piston are in contact with comparatively cool steam, and, therefore, give up a considerable amount of heat. When fresh steam is admitted at a high temperature, it immediately gives up sufficient heat to raise the cylinder walls to a temperature approximating that of the entering steam. This results in the condensation of a certain amount of steam, the quantity depending upon the time allowed for the transfer of heat, the area of exposed surface, and the temperature of the cylinder walls. During the period of expansion the temperature falls rapidly, and the steam, being wet, absorbs a large amount of heat. After the exhaust valve opens, the drop in pressure allows the moisture that has collected on the cylinder

walls to evaporate into steam, so that, during the exhaust period, but little heat is transferred. With the admission of fresh steam at boiler pressure, a mist is condensed on the cylinder walls, which greatly increases the rapidity with which heat is absorbed. The amount of heat lost through cylinder condensation is best shown by a practical illustration. One horsepower is equal to 33,000 foot-pounds of work per minute, or $33{,}000 \times 60 = 1{,}980{,}000$ foot-pounds per hour. This is equivalent to $1{,}980{,}000 \div 778 = 2550$ heat units. The latent heat of steam at 90 pounds gage pressure is 885 heat units; hence, $2550 \div 885 = 3$ pounds of steam at 90 pounds pressure required per horsepower, provided there is no loss of steam, and all of the contained heat is changed into useful work. From 30 to 35 pounds of steam are required in the average simple non-condensing high-speed engine. The most effective method of reducing condensation losses is by so designing the engine that expansion occurs in two or more stages as in compound and triple-expansion engines.

CONDENSATION IN STEAM MAINS. When steam is turned into the piping system, part of it comes in contact with the inner surface of the pipe and fittings, thus transferring part of the heat to the metal of the pipe, from which it is transferred to the atmosphere surrounding the pipe. As the air near the outside surface of the pipe becomes heated to a higher temperature than that of the surrounding air, it quickly expands and rises, thus making room for cooler air which is, in turn, heated and rises, carrying the heat away with it. In this way, a continuous stream of cool air passes over the surface of the steam pipes, causing part of the steam to condense, or change back into the form of water. The condensation that occurs when steam fills the pipe, but is not flowing through it, is known as "static condensation," and that which occurs while the steam is flowing, is known as "dynamic condensation." The amount of condensation has been found to be practically the same in both cases. In order to prevent excessive heat radiation and the resulting condensation losses, the steam piping system should be well covered or lagged with a good grade of non-conducting covering material. No matter how carefully the steam piping is covered, however, some water is still likely to accumulate in the system, due to condensation; therefore, the piping should contain no low spots or pockets in which water can collect.

CONDENSER. The purpose of attaching a condenser to a steam engine or turbine is to obtain a reduction in the back pressure, on the exhaust side, by the formation of a partial vacuum in the chamber into which the engine exhausts. The effect of a condenser is either to increase the power of an engine at a given steam consumption or to reduce the steam consumption for a given power. Condensers may be divided into two general classes:

In one class the condensing water is mixed directly with the steam, and in the other class the condensing water and steam are kept separate, condensation being effected by contact of the steam with metallic surfaces which are cooled by the continuous circulation of the water. The first class includes jet condensers, barometric or siphon condensers, and the ejector type, whereas, in the second class are the different designs of surface condensers.

Jet Condensers. — In a jet condenser, the steam and condensing water mingle in the condensing cone, and the condensed steam is discharged with the water. As the condensing water acts directly upon the steam by actual contact, it will produce a greater drop in pressure for a given amount of water than when used in a surface condenser.

Surface Condenser. — In the operation of a surface condenser, the exhaust steam from the engine enters the shell at the top and fills the condensing chamber, flowing around and among the tubes, while the cooling water is made to pass through them by means of the circulating pump. The steam is condensed by contact with the cold surfaces of the tubes, and drops to the bottom of the shell where it flows to one end and enters the air or vacuum pump and is discharged into the hot-well.

Barometric or Siphon Condensers. — The barometric or siphon condenser is particularly adapted to plants in which the condensing water is suitable for boiler feeding, and also to any plant where condensation of steam only is desired, the condensing water not being used. In operation, the condensing water passing through the annular orifice formed by the nozzle flows downward in a cone-shaped film into the combining tube, where its velocity is sufficiently increased to enable it to carry air along with it, thus producing a vacuum in the steam exhaust pipe. The steam flows downward through the regulating nozzle and into the cone-shaped film of water where it is condensed.

Ejector Condenser. — The ejector type of condenser is so constructed that the exhaust steam from the engine passes through a series of inclined nozzles and mixes with a stream of condensing water that flows through the nozzles. Ejector condensers may be utilized to draw up the condensing water. The exhaust steam moves with considerable velocity and, when the steam and water meet, the steam is condensed and flows downward with the moving column of water into the hot-well. The discharge end of the pipe is sealed by the water in the hot-well and the velocity of flow overbalances the pressure on the well.

CONDENSER, ELECTRICAL. An electrical condenser is an apparatus for accumulating a large quantity of static electricity. Conductors separated by some non-conducting material called the dielectric form a condenser. A simple form of condenser consists of a large number of sheets of tin foil separated by alternate insulating sheets, such as wax paper or mica.

There is no electrical connection between these two sets of sheets and each set forms a terminal. If these terminals are connected with a battery, an electrostatic charge will be stored up in the condenser. If the battery is disconnected and the condenser terminals connected, the charge will flow out, resulting in a current of short duration. The condenser seems to acquire a counter electromotive force which becomes equal and opposite to that of the battery.

Condensers may be divided into different classes according to the kind of dielectric used, there being air, mica, glass, paper, and electrolytic condensers. *Air condensers* have very low capacity and are seldom used except for standards of small capacity. The use of *mica condensers* is also confined largely to standards. *Glass condensers* are especially adapted for high tension, such as is required in wireless telegraphy. The Leyden jar is a well-known form of glass condenser. *Paper condensers* consisting of alternate sheets of tin foil and tissue paper, are widely used for telephone and telegraph work. *Electrolytic condensers* may have acid cells, sodium cells, or aluminum cells. The aluminum cell type is widely used as a lightning arrester on power circuits.

CONDENSER, SYNCHRONOUS. When a synchronous motor is operated idly, that is, without carrying any mechanical load, and simply supplies a wattless current for correcting the power factor of an installation, it is termed a *synchronous condenser*. It is used for power-factor correction and for maintaining constant voltage by power-factor control.

CONDENSING WATER COOLING TOWER. See Cooling Towers.

CONDENSITE. Condensite is a hard substance used as an electrical insulating material. The chief constituent of condensite is a resinous gum, made by the reaction between phenol and formaldehyde, condensite being produced by combining this gum with a hardening agent at high heat. The advantages of this insulating material are that it is non-inflammable, infusible at any ordinary temperatures, insoluble in oil and in most acids and other solvents, and that it shrinks only 0.2 per cent in molding. It can be used either for plastic molding, or for impregnating wood, paper, cardboard, rubber, leather, etc., or as a cement for fastening together the parts of porcelain insulators, for sealing terminals in porcelain bases, etc. A thickness of $\frac{3}{16}$ inch of this material has a puncturing voltage of about 12,000 volts. At a temperature of 170 degrees F., this is reduced to about 5000 volts.

CONDUCTION. The passage of heat from one body to another, or from one part of the same body to another part at a lower temperature, is called *conduction*. Heat from the furnace reaches the water within a boiler by conduction through the plates, and is diffused throughout the entire volume by the same process, assisted by *convection*. Heat which is transmitted

through the air by the vibration of the surrounding ether is called *radiant heat.* This does not warm the air directly, but is absorbed by the objects in its path, which, in turn, give it to the air by conduction. Much of the heat absorbed by the plates directly above the fire in a boiler is radiant heat.

CONDUCTIVITY. Conductivity may be defined as the capacity of any substance to conduct an electric current. The conductivity depends largely upon the physical state of the substance. For instance, the conductivity of air decreases very rapidly as its pressure increases, while rarefied air makes a good conductor of electricity. The conductivity of all substances materially alters with a change of temperature. The substances which are used for conductors of electricity in commercial work are limited to copper, aluminum, and iron. Of these, the first is preëminently the best, while next in order comes aluminum. See Copper Conductivity.

CONDUCTOR. A conductor, in the sense in which this word is used in electrical engineering, is a wire or combination of wires, not insulated from one another, suitable for carrying a single electric current. The term *conductor* should not be used to include a combination of conductors insulated from one another, which would be suitable for carrying several different electric currents. Such a combination of conductors should be termed a *cable.* The maximum current which a conductor can safely transmit is known as its *carrying capacity.* Heat is developed whenever an electric current flows through a conductor, the amount being directly proportional to the resistance of the conductor and the square of the flowing current. The allowable safe temperature rise is one of the limiting features of the current-carrying capacity of any conductor, and, if the heat develops faster than it can be dissipated from the surface, the temperature will rise. See also Kelvin's Law.

CONDUCTOR MATERIALS. The materials most commonly used for electrical transmission are copper and aluminum. Of the two, copper is the better material and is used most extensively. It has a higher conductivity, greater mechanical strength, greater durability, is more ductile, and is not so easily damaged in handling. For sizes of the same conductivity, aluminum wire has about one-half the weight of copper but the diameter is 1.37 times that of copper; consequently aluminum wire exposes a greater surface to wind pressure, and for sleet to form upon, and thereby imposes greater strains on the supporting poles or towers, and limits its use to shorter spans than can be used with copper. Because of the larger diameter and lightness, aluminum conductors are useful for transmitting power at high voltages which would produce a large corona loss with copper conductors having the same conductivity as aluminum. One of the greatest disadvantages of aluminum for conductors is that it has less mechanical strength than

copper. This necessitates either using greater sags and higher poles or towers, or spacing the towers closer together. In either case, the cost of the supporting structures is greater than with copper conductors, and this greater cost will usually more than offset the saving gained by the lower cost of the aluminum conductors. In order to take advantage of the larger bulk and lightness of aluminum, and yet have mechanical strength equal to, or greater than, copper, a composite cable has been put into commercial use. This cable consists of a center core of high strength steel wire wrapped with a number of strands of aluminum wire. The steel is depended upon for the greater part of the supporting strength, although the aluminum wires aid somewhat. In addition to copper and aluminum, bi-metallic copper-steel and steel wires are used. They have lower conductivity than the copper or aluminum, but have greater mechanical strength, and are used for long spans across rivers, etc., for overhead ground wires, and for short lines in which the power to be carried is so small that, if copper wires were used, they would have to be unnecessarily large for mechanical reasons. Bi-metallic wire is a composite wire having a steel center and a copper coating.

CONDUCTOR SIZES, STRANDED. See Stranded Conductor Sizes.

CONE CLUTCH. A friction clutch in which one friction surface is in the form of a frustum of a cone and which, for engagement, is forced into the other member which is made to fit it on the inside. One friction surface is often leather covered. These clutches are widely used in many classes of machinery.

CONE MUFF COUPLING. A coupling consisting of a split sleeve each end of which is cone-shaped on the outside and which surrounds the two ends of the shafts to be coupled together. The sleeve is surrounded by two rings, one on each end, having tapered bores fitting the conical ends of the sleeve. These two rings are clamped together by means of bolts and nuts and in clamping the rings together the split sleeve is forced to bind firmly over the two shafts. See also Compression Coupling.

CONE-PULLEY. A cone-pulley is, in reality, a stepped-pulley having, usually, from three to five different diameters for securing a like number of speed variations by shifting a belt from one " step " to another, cone-pulleys being used in pairs with the largest step of one cone-pulley opposite the smallest step on the other cone-pulley. Usually cone-pulleys are made with uniform steps; that is, the difference in diameter between the various steps is the same. When the centers of the shafts on which the cone-pulleys run are a fair distance apart, so that the belt passes very nearly halfway around each of the cones on which it is running, this method of making the cone-pulleys will prove satisfactory. The length of the belt

will then be approximately equal to twice the distance between the shafts added to half the circumference of the step on one of the cones on which the belt is running, plus half the circumference of the step on the other cone engaging with the belt. When the shafts are nearer together, however, so that the belt makes a large angle with the line passing through the centers of the cones, or when there is a large difference between the largest and the smallest steps of the cone, it is not possible to obtain satisfactory results by merely designing the two pulleys with equal differences between the steps, because the length of belt required on the largest and smallest steps will be different from the length required on the two middle steps.

CONNECTICUT RIVER RULE. A rule employed for finding the board measure of logs. It is as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

CONNECTION BARS. The name "connection bars" is usually applied to all connections on switchboards, between apparatus and bus-bars, and between different devices comprising the switchboard equipment. Wire is generally used up to 260 amperes, above which size bars are almost invariably used. Connections are usually bare up to 650 volts; above this voltage and up to 13,200 volts, they are usually insulated; above 13,200 volts, they are, as a rule, bare, and it is considered safer to warn the attendant to keep away from such conductors rather than to depend upon insulation which may deteriorate.

CONSERVATION OF ENERGY. Energy exists in various forms, such as mechanical, molecular, and chemical energy. It is stored in all kinds of fuel, and is made apparent by chemical reactions, by muscular effort, and by other means. Heat is a form of energy and the potential heat energy in coal originally was received from the sun. According to the important law of the conservation of energy, the latter may be transformed directly or indirectly from any one form into any other form, but the total amount of energy must forever remain the same. Energy can neither be created nor destroyed which accounts for the fact that "perpetual motion" is impossible. The various processes by which energy is utilized are simply means for transforming it from one form into another. The steam engine changes heat energy into mechanical energy, and the percussion of a bullet against a rock converts mechanical into heat energy. A body just at the point of falling from an elevation has a store of potential energy. As it falls its velocity increases, and its potential energy is gradually changed into kinetic energy.

CONSERVATION OF MASS. A chemical law applying to all chemical reactions, which states that whenever a change in the composition of substance takes place, the amount of matter after the change is the same as before the change.

CONSTANTAN. The alloy known as *constantan* is used for resistance wire in electrical instruments, and also to form one element in base-metal thermocouples. It contains about 60 per cent of copper and 40 per cent of nickel. Its electrical conductivity is only about one-thirtieth of copper; hence, its value as a resistance wire.

CONSTANTS IN MATHEMATICS. A constant is a value that does not change or is not variable. However, constants at one stage of a mathematical investigation may be variables at another stage, but an *absolute constant* has the same value under all circumstances. The ratio of the circumference to the diameter of a circle, or 3.1416, is a simple example of an absolute constant. In the common formula used for determining the indicated horsepower of a reciprocating steam engine, the product of the mean effective pressure, the length of the stroke in feet, the area of the piston in square inches, and the number of piston strokes per minute is divided by the constant 33,000, which represents the number of foot pounds of work per minute equivalent to one horsepower. Constants occur in many mathematical formulas and frequently a single value or constant represents one or more other values which have been eliminated to simplify the formula. For example, when there is a constant in both numerator and denominator, the formula may be simplified by dividing the numerator constant into the denominator constant, thus eliminating the former.

CONTACTORS. The magnetically-operated switches of which magnetic control equipments principally consist are known as "contactors." This term is very generally understood as applying to a switch which closes by the application of current to a magnetic coil and is held closed by the continued application of current to the same coil. Complete lines of contactors have been developed, both for direct and alternating current, which are applicable, by the use of suitable auxiliaries, to any required arrangement of motor circuits. Contactors are designed to operate many thousand times without replacement of electrical parts, and several million times before wearing out mechanically.

CONTINUOUS MILLING. In any scheme of so-called "continuous milling" the object is to keep the cutters at work the maximum time possible. Continuous milling machines are of the rotary work-table and planer-table types. The rotary table machine is set with its table axis either vertical or horizontal; the work being spaced compactly around the table, and the successive parts milled as they are fed past the revolving

cutters. The vertical-axis type has the advantage of easy loading and inspection of the cutter at work, while the horizontal-axis table can be made to work between opposed cutters, which mill the pieces on both ends simultaneously and to length.

The planer-table type of machine may be used for continuous milling in several ways. The work pieces may be strung on the table and milled with the table feeding " against the cutter " until the limit of traverse is reached, the feed then being reversed to travel " with the cutter," after which the work is removed. The objection to this method is the difference in cutter action on the forward and return feed. Another method is to remove parts as soon as they are milled and then return the table by a quick traversing motion. Still another method of continuous milling on planer-type machines is known as the removable platen method. The work is loaded onto a short platen held on a bench alongside of the machine; the platen is then hoisted and lowered onto the ways. A rack on the under side engages the longitudinal feed-screw and feeding toward the cutter begins. Meanwhile, a platen ahead carrying similar parts has passed beyond the cutters and is ready to be unloaded. This is hoisted and trolleyed to the head end of the machine and lowered onto the bench, where the work is removed and more pieces put on. The operation is thus kept up continuously. The minimum number of platens required is two, but three, four or five are often used.

CONTRACTING CHILL. A metal mold used for making chilled cast-iron car wheels which is so designed that when the molten metal is poured into it, the entire surface will contract, decreasing the diameter, and thus following up and remaining in contact with the shrinking metal of the cooling wheel.

CONTRACTS, ROYALTY. See under Royalties on Patents.

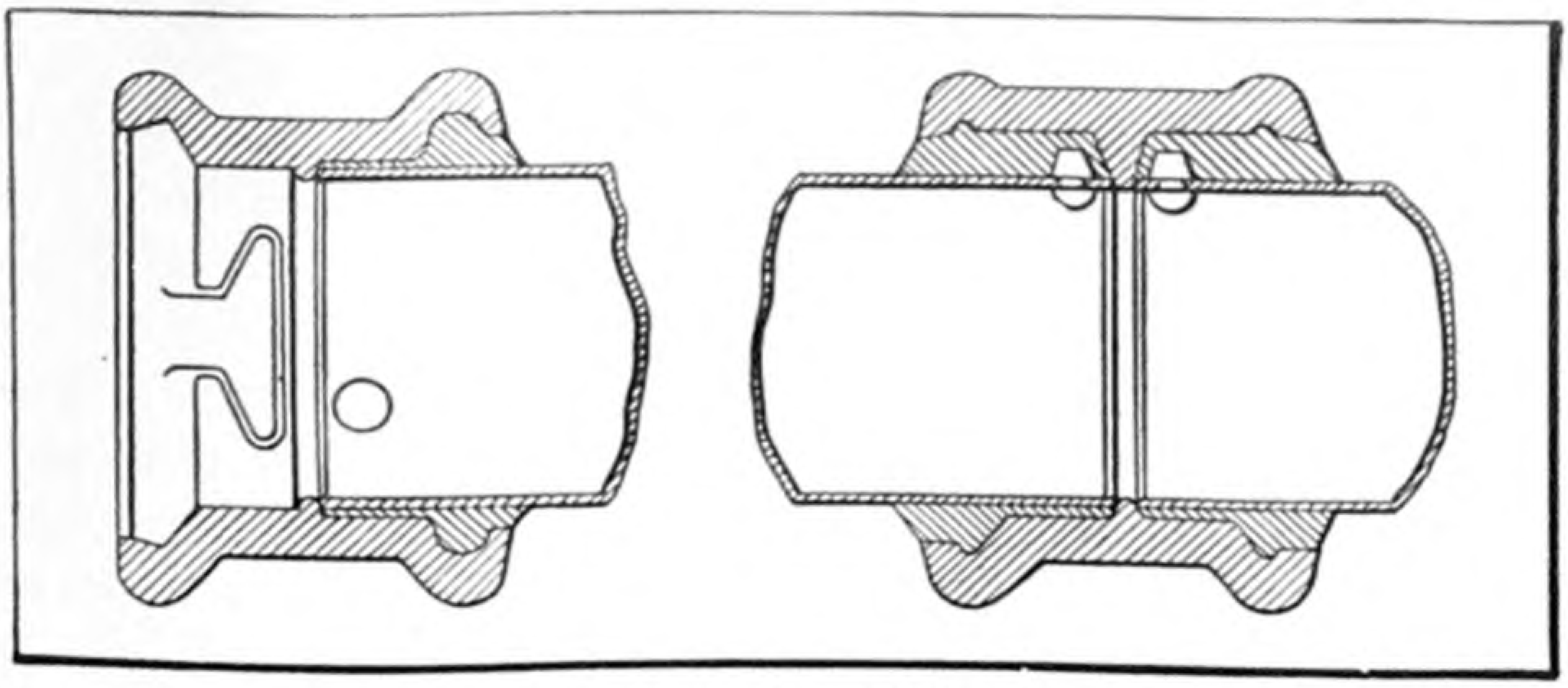
CONTROLLER, ELECTRIC. A starting rheostat for controlling the current when starting a motor. It prevents excessive current inrush and brings the motor gradually up to its normal speed. Controllers may be either hand-operated or power-operated. Different types are also required for different kinds of motors.

CONTROL SWITCHES. A control switch is used to control the operation of a remote control device, such as a motor or solenoid-operated oil switch, a circuit-breaker, or a rheostat, or a governor motor of a steam engine, water turbine, or other prime mover. It may also be used to close or open circuits, to trip circuit-breakers, oil switches, etc., from some distant point. Control switches are made up in several different forms, such as the plain lever switch type, the drum controller type, and the pull-and-push-button type. They may be single-throw or double-throw, and either single, double, or triple pole, depending upon the service for which they are intended.

These switches are usually of small current capacity (under 50 amperes) and are not, in general, called upon to break much current.

CONVECTION CURRENTS. The currents set up within a liquid, due to temperature differences in different parts, are called *convection currents*, and are important in causing the water to circulate over the heating surfaces within a steam boiler. See also Conduction.

CONVERSE LOCK-JOINT. The Converse lock-joint is a leaded joint used for water piping which does not have to stand very high pressure. The joint consists of a special cast-iron coupling or hub (see illustration) into which the ends of the pipes to be joined are fitted. This hub has an



Converse Lock-joint

annular groove at each end and, in addition, two T-shaped grooves, one of which is shown in the illustration to the left. The pipe has two holes punched a short distance from the end on opposite sides into which rivets are driven. One of the holes for the rivets is shown in the illustration to the left, while the rivets themselves are indicated in the section to the right. In making this joint, the heads of the rivets slip into the T-shaped slots of the hub, after which the pipe is turned slightly, locking the pipe into the hub, and preventing it from being pulled out endwise. The joints are then made tight by pouring lead into the annular groove and calking.

CONVERTER. A large pear-shaped vessel holding from ten to fifteen tons of molten iron, employed in the *Bessemer process* for converting pig iron into steel; or the barrel- or trough-shaped vessel used in the refining of copper by a method known as the *Manhès* or *converter process*.

CONVERTERS, SYNCHRONOUS. See Synchronous Converters.

CONVEYOR. A device for handling and conveying heavy and bulky materials, such as coal and ore, as well as small machine parts of various description, from one part of a plant to another. Conveyors are constructed either to move the material horizontally or to raise it to a higher level.

There are different classes of conveyors. See **Belt Conveyors; Bucket** Conveyors; Screw Conveyors.

COOLANT. The term "lubricant" is commonly applied to a fluid used on metal-cutting tools, but as the cooling action of this fluid is by far its most important function, the term "coolant" is more strictly accurate and is now used quite generally. See Cutting Oils and Compounds.

COOLING TOWERS. From 20 to 30 per cent may be saved in fuel by the use of a condenser, assuming that the water used for condensing the steam can be obtained free of cost. When a power plant is located in a city where the water must be obtained at regular city rates, it may be more economical to run non-condensing than to purchase cooling water. In order to do away with the water expense, so-called *cooling towers* are extensively used. By means of these towers, the condensing water may be cooled and used over and over again with a comparatively small loss by evaporation. There are various forms of cooling towers in use but the general principles are practically the same in each case. The tower, generally, consists of a steel shell inside of which are suspended a number of mats of a special steel wire cloth, galvanized after weaving. The mats are, in effect, a metallic sponge, capable of holding a large quantity of water in suspension which accumulates and drips off into the reservoir at the bottom. The water to be cooled is pumped to the top of the tower and discharged through a number of distributing nozzles upon the tops of the mats. From here it drips to the bottom, exposing a large surface to the air which may be forced upwards by fans placed at the bottom of the tower. Towers are also made for natural draft, in which case the flue is extended to a considerable height above the cooling surfaces.

COORDINATES. In analytical geometry, coordinates are the distances, measured parallel to the coordinate axes, which locate a point. In plane analytical geometry, there are two coordinates, the *abscissa* and the *ordinate*. In analytical geometry in three dimensions, there are three coordinates.

COPAL. Copal is a resinous product used as an electrical insulating material in the form of a colorless varnish obtained by dissolving in alcohol, turpentine, or linseed oil. As an insulating material, it has several disadvantages, however, because it melts at a low temperature, it is very inflammable, and it is brittle, when cold. The puncturing voltage is about 10,000 volts for a thickness of about $\frac{1}{8}$ inch, and 20,000 volts for a thickness of about $\frac{1}{4}$ inch.

COPE. In foundry practice, the cope is the upper part of a flask used for molding.

COPPER. Copper is a very malleable ductile metal that is widely used. The specific gravity of pure copper is 8.94, but varies between 8.91 and 8.95,

according to the treatment to which it may have been subjected. Ordinary commercial copper is somewhat porous and the specific gravity ranges all the way from 8.2 to 8.8. The melting point of pure copper is 1083 degrees C. (1980 degrees F.), but ordinary commercial copper will melt at a somewhat lower temperature, usually about 1940 degrees F. The linear expansion per unit length per degree F. is 0.00000887. The specific heat at 32 degrees F. is 0.0899, and at 212 degrees F., 0.0942. In heat conductivity, copper ranks next to silver, and is superior, in this respect, to all other metals. The heat conductivity is 73.6 per cent of that of silver. In electrical conductivity copper also ranks next to silver, and if the conductivity of silver is assumed as equal to 100, that of copper varies from 96.4 to 97.7, according to its condition.

There are several hundred copper minerals, but the more important ores are not more than about a dozen in number. The most important are the sulphide ores. There are three methods by means of which copper may be obtained from its ores: The first of these methods, the dry method, cannot be profitably employed for ores containing less than 4 per cent of copper. This method is frequently referred to as copper "smelting." The second method, the wet method, is preferred for ores that are very poor in copper, that is, those that contain less than 4 per cent of metal. The third or electro-metallurgical method is very largely used for all classes of ores, but especially for ores containing a comparatively small amount of precious metals, as in this case the ore may be profitably subjected to an electrolytic treatment, the copper being recovered together with the silver and gold present in the ores.

The tensile strength of cast copper varies from 20,000 to 30,000 pounds per square inch; the compressive strength is about 40,000 pounds per square inch; and the modulus of elasticity, 10,000,000. Annealed copper wire has a tensile strength of 35,000 pounds per square inch, and a modulus of elasticity of 15,000,000; unannealed wire has a tensile strength up to 60,000 pounds per square inch, and a modulus of elasticity of 18,000,000.

COPPER ALLOYS. See Admiralty Metal; Aich Metal; Ajax Metal; Aluminum Alloys; Baily's Metal; Bell Metal; Benedict Metal; Bismuth Bronze; Chinese Alloys; Constantan; Copper-zinc-aluminum Alloy; Copper-tin Alloy; Copper-tin-lead Alloy; Copper-tin-lead-zinc Alloy; Copper-tin-zinc Alloy; Delta Metal; Deoxidized Bronze; Dutch Metal; Electrolytic Copper; English Gear Bronze; Gurley's Bronze; Japanese Alloys; Muntz Metal; Ounce Metal; Plastic Bronze; Red Brass.

COPPER ALLOY STEEL. A steel containing a small percentage of copper and nickel, and sometimes chromium, which has been found suitable as a substitute for more expensive alloy steels. A steel containing from 1.5 to 1.8 per cent of nickel and from 0.5 to 0.8 per cent of copper is equal in its

properties to a 3 per cent nickel steel. If 0.5 per cent of chromium is added to this alloy steel, the physical properties will equal those of nickel-chromium steel containing 3 per cent of nickel and 1 per cent of chromium.

COPPER-ALUMINUM ALLOY. An alloy containing about 90 per cent of copper and 10 per cent of aluminum is remarkable for its high tensile strength, its resistance to corrosion, and its wearing qualities. It is used for worms, accurately fitted bearings, and in places where ability to resist the corrosive action of salt water, and tanning and sulphite liquids is required. The physical properties resemble those of 0.35 per cent carbon Bessemer steel, and are about as follows: Ultimate tensile strength, 70,000 pounds per square inch; elongation in two inches, 20 per cent; reduction in area, 21 per cent; specific gravity, 7.5; Brinell hardness number, 500-kilogram load for 30 seconds, from 90 to 100; shrinkage allowance, 0.22 inch per foot; elastic limit, in compression, 19,500 pounds per square inch. This bronze is about 10 per cent lighter than either yellow brass or manganese-bronze; 17 per cent lighter than phosphor-bronze; and 15 per cent lighter than red brass.

COPPER BLAST FURNACE. A blast furnace used for smelting copper ore. It is much smaller in size than the blast furnace used for iron ores. The furnace is made either round or rectangular in section, the round furnace being used for outputs from 50 to 70 tons a day, and the rectangular furnace for larger amounts. The round furnace may be up to 4 feet in diameter and is made 14 feet high. Rectangular furnaces are made not more than 4 feet wide and are also made 14 feet high, but are made as long as required.

COPPER CASTINGS. So-called "pure copper" castings ordinarily contain from one to three per cent of zinc. These are used in electrical installations and for die-blocks on electric welding machines. The conductivity, as compared with silver = 100, is not more than 60 per cent. Pure commercial copper containing from 99.6 to 99.9 per cent of metallic copper has a conductivity from 70 to 85 per cent of that of pure silver. Hence, the impurities in ordinary copper castings impair, to a great extent, its value as an electrical conductor.

COPPER-CLAD STEEL. A material generally used in the form of wire, in which a steel wire is covered with a coating of copper. It is produced either by alloying the copper with the surface of the metal or by welding it onto the surface. When the copper is alloyed with the surface, it is brought to a molten state before being applied, while, when welded to the surface, it is merely in a plastic state.

COPPER COLORING. To color copper articles, such as ash trays, pin dishes, receivers, etc., a solution of ammonium sulphide will give good results

for the beginner. The greatest variety of colors, from light brown to black, can be obtained by this simple method. Use a dilute solution, cold. A good working solution is produced by diluting a saturated solution of ammonium sulphide with from 10 to 40 parts of water. A light brown color is produced by dipping the work for a very short time in the solution, withdrawing it, and allowing it to dry in the air. A darker shade of brown is obtained by a longer immersion, according to the color desired, after which the work is allowed to dry in sawdust. To obtain a black coloring, allow the article to remain for some time in the bath, and, after removing, dip it in alcohol, after which the alcohol is burnt off, leaving a black coating. These colors can be permanently fixed by a transparent lacquer. The objection to ammonium sulphide is the great care necessary in handling, as it leaves an indelible stain upon the fingers, and also has a very obnoxious odor. The ammonium sulphide also decomposes in time, depositing sulphur. It should be kept in a dark-colored bottle provided with a glass stopper. It is not good for brass, being adapted only for copper.

Another solution for coloring copper which yields very good results is composed of copper nitrate, 1 part; water, 3 parts. This solution forms a deposit of copper salt, and, if heated, the salt is decomposed into a black copper oxide. The greenish tints are obtained by the following solution: Ammonium carbonate, 2 ounces; ammonium chloride, $\frac{2}{3}$ ounce; water, 16 ounces. This solution gives good results on both copper and brass, different colorings being obtained by repeated dippings in the solution, allowing ample time between each for the articles to properly dry.

COPPER CONDUCTIVITY. The following are the normal values for standard annealed copper according to the Standardization Rules of the American Institute of Electrical Engineers.

1. At a temperature of 20 degrees C., the resistance of a wire of standard annealed copper one meter in length and of a uniform section of 1 square millimeter is $\frac{1}{58}$ ohm = 0.017241 ohm.

2. At a temperature of 20 degrees C., the density of standard annealed copper is 8.89 grams per cubic centimeter.

3. At a temperature of 20 degrees C., the "constant mass" temperature coefficient of resistance of standard annealed copper, measured between two potential points rigidly fixed to the wire, is $0.0039\dot{3} = 1/254.45$ per degree centigrade.

4. As a consequence, it follows from (1) and (2) that, at a temperature of 20 degrees C., the resistance of a wire of standard annealed copper of uniform section, one meter in length and weighing one gram, is $(\frac{1}{58}) \times 8.89 =$ 0.15328 ohm.

COPPER HARDENING. It is quite commonly believed that the hardening of copper as practised by the ancients is a "lost art," but present-

day metallurgists not only understand how the ancients hardened their copper and bronze, but also know how to produce copper and bronze products that are even harder than specimens which have been discovered. Cutting edges on swords, daggers, knives and other implements developed by the ancients were obtained by hammering the metal, or, in other words, cold-working. These old metal-workers not only hand-hammered their copper implements but also used the same means to harden bronze articles.

There are two methods of hardening copper. One consists of alloying the copper with some other metal or several other metals, such as zinc, tin, nickel, cadmium, chromium, cobalt silicon, aluminum, iron, beryllium and arsenic; the second consists of cold-working the metal or copper alloy. In fact, it is possible to work the metal to such a state of hardness that a slight amount of additional work will cause it to break. The explanation of all copper hardening may be attributed to one of these methods or a combination of both. Photomicrographs of an ancient copper spear-head indicate that apparently this hardness had been obtained by cold-working. It is possible to produce copper scissors, knives, and other cutting tools, but unless a special reason exists for their use, they offer no advantages over tools made from steel. The actual hardness of annealed commercial copper as determined by the Brinell machine is from 40 to 50. The hardness of cold-worked pure copper probably does not ever exceed 120 Brinell. The hardness of copper that has been alloyed with some other metal or a number of metals rarely exceeds 250 Brinell, although a hardness just over 300 has been attained as an upper limit. As a basis of comparison, the Brinell hardness of very "soft" iron is around 80, and of steel used in common cutlery, such as in a pocket knife, about 420 Brinell.

COPPERING SOLUTION. A coppering solution for coating finished surfaces, in order that lay-out lines may be seen more easily, is composed of the following ingredients: To 4 ounces of distilled water (or rain water) add all the copper sulphate (blue vitriol) it will dissolve; then add 10 drops of sulphuric acid. Test by applying to a piece of steel, and, if necessary, add four or five drops of acid. The surface to be coppered should be polished and free from grease. Apply the solution with clean waste, and, if a bright copper coating is not obtained, add a few more drops of the solution; then scour the surface with fine emery cloth, and apply rapidly a small quantity of fresh solution.

COPPER LOSS. The loss of energy which takes place when a current passes through a conductor, whether an armature winding or a transmission wire, is called *copper loss*. It is due to the resistance of the wire. The loss may be computed by multiplying the square of the current in amperes by the resistance of the conductor in ohms. The loss is then obtained in watts.

COPPER-TIN ALLOYS. There are a number of commercial copper-tin alloys. One known as Stone's English gear-bronze is composed of 89 per cent of copper and 11 per cent of tin. This bronze is used extensively both in the United States and abroad. It is very serviceable for gears and worm-wheels, where the requirements are severe, and especially when quiet running is an important feature. The gear made from this bronze should run with well-finished high-carbon or alloy steel gears. The ultimate tensile strength is from 35,000 to 40,000 pounds per square inch; the elongation in two inches, from 6 to 10 per cent; reduction in area, from 7 to 9 per cent; the specific gravity, 8.5; the Brinell hardness number, 500-kilogram load for 30 seconds, from 70 to 79; the shrinkage allowance, $\frac{1}{8}$ inch per foot, and the elastic limit in compression, 21,600 pounds per square inch.

COPPER-TIN-LEAD ALLOYS. A gear-bronze used for small gears, where the service is not too severe, is composed of 88 per cent of copper, 10 per cent of tin, and 2 per cent of lead. The presence of lead makes the alloy easier to machine. The ultimate tensile strength is from 30,000 to 35,000 pounds per square inch; the elongation in two inches, from 5 to 8 per cent; the specific gravity, 8.8; the Brinell hardness number, 500-kilogram load for 30 seconds, from 65 to 70; the shrinkage allowance, $\frac{1}{8}$ inch per foot, and the elastic limit in compression 18,500 pounds per square inch. An alloy of the same metals, containing 80 per cent of copper, 10 per cent of tin, and 10 per cent of lead, with a small percentage of phosphorus, is used as a standard phosphor-bronze for high speeds and heavy pressures. It is one of the best bearing metals of the phosphor-bronze class, and has been extensively used for bearings subjected to shock and vibration, heavy work, and high speeds.

COPPER-TIN-LEAD-ZINC ALLOYS. An alloy consisting of about 90 per cent of copper, 6.5 per cent of tin, 1.5 per cent of lead, and 2 per cent of zinc has been used as a medium soft bronze in the automobile industry for small bearings lined with genuine babbitt. This metal is especially recommended for bearings where non-corrosive qualities are required, where the speeds are high, or where heavy pressures are likely to be encountered. The lead content is sufficient to give to this bronze conformability, so that if the adjacent part is not closely fitted, the alloy will come to a bearing without cutting. The ultimate tensile strength of this alloy varies from 34,000 to 40,000 pounds per square inch; the elongation in two inches is from 25 to 33 per cent; the specific gravity, 8.8; the Brinell hardness number, 500-kilogram load for 30 seconds, from 50 to 60; and the shrinkage allowance, 0.14 inch per foot. Another alloy in the same class, which, however, is somewhat softer, consists of 81 per cent of copper, 7 per cent of tin, 9 per cent of lead, and 3 per cent of zinc.

COPPER-TIN-ZINC ALLOY. An alloy consisting of 88 per cent of copper, 10 per cent of tin, and 2 per cent of zinc is generally known as "gun-metal," and is used where heavy pressures and high speed require a material of this kind. It is a satisfactory metal for use in the presence of superheated steam and in hydraulic machinery. There is no granular structure in this alloy, and it has, therefore, been widely recommended for high-grade bearing. If so used it must be closely fitted, and should run with hardened and ground shafts only. The ultimate tensile strength of the alloy is from 32,000 to 38,000 pounds per square inch; the elongation in two inches, from 14 to 18 per cent; the specific gravity, 8.7; the Brinell hardness number, 500-kilogram load for 30 seconds, from 70 to 75; and the shrinkage allowance, $\frac{1}{8}$ inch per foot.

COPPER WIRE STRENGTH. The strength of copper wire can be greatly increased by proper methods in the drawing operation. It has been found that the strength can be increased nearly 100 per cent by omitting the annealing process during the latter part of the drawing, at the same time making the steps of gradations between the successive dies smaller. In this manner, copper wire will obtain a very hard surface, and is known as "hard drawn." The increase in strength is greater for smaller diameters, as the treatment will affect a proportionately larger part of the cross-section. A No. 8 copper wire (0.165 inch in diameter) can be given a strength of 62,000 pounds per square inch of cross-section, while a No. 12 wire (0.104 inch in diameter) may obtain a strength of 64,500 pounds per square inch. As ordinary commercial copper wire has a tensile strength of only 32,000 pounds per square inch, the effect of correct methods in drawing is very marked. The modulus of elasticity is increased by these methods from 12,000,000 to 19,000,000 pounds, but the elongation is reduced from 35 to 1.25 per cent. It should be noted that this change is effected entirely by manipulation in the drawing, and not by the addition of any alloying metal.

COPPER-ZINC-ALUMINUM ALLOYS. One of the alloys in this group is composed of 56 parts copper, 43.5 parts zinc, 0.5 parts aluminum, with a very small amount of manganese. This alloy and others, varying chiefly as to their copper and zinc content, are commonly known as "manganese-bronze." Such alloys are used for castings where great strength and toughness are required, especially for propeller blades and hubs, valve stems, engine frames, and other parts requiring great strength. They are the best bronzes for all requirements of this kind, but they do not make good bearing bronzes. The physical properties of the composition given are as follows: Ultimate tensile strength, 70,000 pounds per square inch; elongation in two inches, from 22 to 35 per cent; specific gravity, 8.4; Brinell hardness number, 500-kilogram load for 30 seconds, from 104 to 119; shrinkage allow-

ance, $\frac{1}{4}$ inch per foot; elastic limit in compression, 40,000 pounds per square inch.

CORD. In the measure of wood, a cord equals a pile 4 by 4 by 8 feet, or a cubical content of 128 cubic feet.

CORDEAUX THREAD. The Cordeaux screw thread derives its name from John Henry Cordeaux, an English telegraph inspector who obtained a patent for this thread in 1877. This thread is used for connecting porcelain insulators with their stalks by means of a screw thread on the stalk and a corresponding thread in the insulator. The thread is approximately a Whitworth thread, 6 threads per inch, the diameters most commonly used being $\frac{5}{8}$ or $\frac{3}{4}$ inch outside diameter of thread; $\frac{5}{8}$ inch is almost universally used for telegraph purposes, while a limited number of $\frac{3}{4}$-inch sizes are used for large insulators.

CORE BOARDS. See Cores for Molds.

CORE-BOXES. See Cores for Molds.

CORE LOSS. The power lost in an iron core of an electrical machine on account of hysteresis and eddy currents, taken together, is called *iron loss* or *core loss*. These losses bring about a lowering of the efficiency of the machines, and also cause a heating up of the iron, and thus limit the permissible flux density, or make extra provisions for ventilation and cooling necessary.

CORE PRINT. Many patterns for use in making castings, have projections which form pockets in the mold which can be used in supporting cores to form interior openings in the castings. These projections are called *core prints* as they leave a print or impression in the mold. The core, which has extensions for entering these prints, is made in a separate wooden mold or core-box and it is reinforced with iron rods or wire and baked in an oven to give it greater strength. There are three types of core prints in general use on patterns. Those that are placed on the cope and drag side of a pattern are called *cope* and *drag prints;* those located on the sides or ends, or in any position where there is a joint or parting, are known as *joint* or *parting prints;* and those which are so placed that no parting can be made are called *tail, heel,* or *drop prints.*

CORES FOR MOLDS. Cores for forming passages or openings in castings, are of three kinds: 1. Metal cores. 2. Dry sand cores. 3. Green sand cores. A *metal core* is used in brass or non-ferrous metal work when considerable accuracy in the core is required. Cores of this kind are not used in cast-iron molding. A *dry sand core* is one that is made from a fairly coarse sand free from clay, the sand being mixed with a bond or binder until it is of about the consistency of heavy flour dough. It is then baked until

perfectly dry and hard. A *green sand core* is one which is made from ordinary molding sand — green sand — and which is not baked. This is, by far, the cheapest form of core which can be used, but it is restricted to comparatively simple shapes — usually plain cylindrical shapes — or to pattern forms in which there is a recess, so that the core can be shaped by molding the sand in connection with the regular molding work.

Oil-sand Cores. — For certain classes of core work, excellent results are obtained by the use of sea sand and oil, such as, for instance, the core required for the combustion chamber of a gas or oil engine, or the steam ports of cylinders, when the core is entirely surrounded, and good venting is necessary. Oil-sand cores are very hard and strong, when dry. The principal objection to this kind of core is the disagreeable odor emanating from the oil. The fact that the oils generally used are fish oils is responsible for this odor, but a mixture of 2 parts of whale oil with 1 part of boiled linseed oil gives good results, and has not such an offensive odor. There are also several good core oils on the market which have practically no odor.

Core-boxes. — After the shape or design of a dry sand core has been determined by the patternmaker, a mold must be constructed in which the core may be formed. This mold is called a *core-box*, and should always be marked in such a way that it will be kept with the pattern to which it belongs. The making of core-boxes for dry sand cores is an important part of the patternmaker's work. There are two general classes of core-boxes, *viz.*, those that form complete cores and those that form cores partly by means of the core-box and partly by strickling; the latter are called *skeleton* or *frame* core-boxes.

Core Boards. — Core boards are used when sweeping up cores with strickles. The outline of the board governs the lengthwise form of the core, while the strickles give it sectional shape. Core boards are used largely for pipe work and where but one or two castings are to be made. A core made on a board cannot be removed until it is dried, so that the board must be put in the oven along with the core. These boards do not last very long when made of wood, and if they are to be used a number of times, it is preferable to make them of cast iron.

Core Machines. — When many cores are to be made of small size and cylindrical in shape, core machines are sometimes used to good advantage. The advantages of core-making machines are that the work is produced more rapidly and uniformly than by hand and no core-boxes are required.

Core-barrel. A core-barrel, generally made from cast iron, is employed in the making of large cores in the foundry. Instead of making the cores solid, loam is applied to the outside of the core-barrel, the barrel being first wound with rope and the loam mixture applied in a comparatively soft state. The barrel is turned during this process so that the core is formed to a circular

section at all points by means of a strickle, which may be shaped to form any contour on the surface of round cores.

Core Oven. — Ovens used for drying cores in the foundry generally are made large enough so that a truck with a table and shelves for supporting the cores may be wheeled right into the oven. Shelves are sometimes provided on the sides of the oven on which to place the cores.

COREX. An abrasive which is used in the manufacture of wheels for grinding cast iron, unannealed malleable iron, brass, bronze, etc., is known as *corex*. It is produced from coke and sand in the electric furnace.

CORK. Cork is obtained from the outer layer of the bark of an evergreen species of oak, growing in the south of Europe and on the north coast of Africa. Water and many liquids have no deteriorating effect upon cork, and it may be compressed many thousand times without changing its molecular structure. An important application of cork is for cork inserts in friction clutches, owing to the fact that cork has a high coefficient of friction, probably double that of wood or leather on iron. As a rule, the cork, which has previously been boiled and softened, is forced into holes formed in one of the metallic friction surfaces so that it slightly protrudes above the surface. When the clutch is engaged, the cork will engage the opposing friction surface first, but if sufficient pressure is applied to the clutch, the cork is pressed down flush with the metal surface and acts with it in carrying the load. The coefficient of friction with cork-insert surfaces has been found to average about 0.34, while the average coefficient of friction of cast iron on cast iron is about 0.16, and of bronze on cast iron, about 0.14.

CORLISS CYLINDER-BORING MACHINES. Corliss engine cylinders are commonly bored on a special type of machine which resembles a regular cylinder boring machine of the horizontal design, excepting that, in addition to the regular boring-bar, it has two boring-bars for boring the ports into which the steam and exhaust valves are inserted. On a machine of typical design, this port boring attachment consists of two columns which are adjustable along parallel beds attached to the sides of the main bed. One of these columns carries two boring-bars, each mounted on a separate saddle. The saddles are adjustable vertically in order to align the boring-bars with the port holes at varying heights and center-to-center distances. The column on the opposite side of the bed is of smaller size, and carries the outboard bearings that steady the port boring-bars.

CORLISS ENGINE. Steam engines of the Corliss type are equipped with Corliss valves. There are four cylindrical valves, — two steam valves at the top and two exhaust valves at the bottom. These valves are given an oscillating movement. The advantages of this type of valve-gear,

as compared with a plain slide valve, are that it permits an earlier cut-off and greater range of expansion, a more perfect steam distribution, and a smaller clearance space.

CORONA LOSS. When the voltage of an overhead transmission system or of conductors in general exceeds a certain critical value, depending upon the spacing and diameter of the wires, there will appear on the surface of the conductors a halo-like glow to which the name " corona " has been given. Apart from this luminous effect, the appearance of the corona is accompanied by a certain loss of power, proportional to the frequency and the square of the amount by which the pressure between the conductors exceeds a certain value known as the " disruptive critical voltage." The action of corona on insulation manifests itself chemically, mechanically, or by heat. At high altitudes particularly it is not advisable to use the smaller sizes of wire because of the corona loss, or the loss due to the breaking down of the air insulation.

COROWALT. Corowalt is a special corundum abrasive that is adapted for grinding hardened low- or high-carbon steel. Corowalt is produced in the electric furnace in a manner similar to that of alundum.

CORRECTED ADDENDUM. See Addendum.

CORROSION. The forming of an oxide on the surface of a metal; specifically, the forming of rust (iron oxide) on the surface of iron and steel.

CORRUGATED FLANGES. The plain face corrugated type of joint for pipe flanges is a plain face straight flange upon which concentric curves have been cut with a round-nosed tool. On some types of installations, a face of this kind is necessary, as the corrugations have a tendency to prevent the gaskets from blowing out, particularly when the flow in the pipe line is of a nature that requires the use of exceptionally thick gaskets.

Plain Face Scored Joints. — This type of joint is made by using a plain straight flange with scores upon the face consisting of concentric rings made with a diamond-pointed tool. On oil or acid lines, where the gaskets must be of lead, a joint of this kind gives the best satisfaction, as the lead gasket squeezes into the scores and assists in maintaining a tight joint, without any undue strain on the bolts and flanges.

CORUBIN. Corubin is an artificial corundum obtained from the slag produced by the Goldschmidt thermit welding process. It is much purer than the natural corundum and will resist sudden and great changes of temperature without breaking. Chemical vessels made of fireclay and corubin may be heated red-hot and plunged into cold water without breaking, or even showing any tendency to crack.

CORUNDUM. Corundum is an aluminum oxide which is found in nature as crystals which are usually rough and rounded, or massive, with nearly rectangular partings. There are many varieties of corundum, the finely-colored transparent varieties including such gem-stones as the ruby and sapphire, while the impure, granular, and massive forms are known as *emery*. The term " corundum " is often restricted to the remaining kinds; that is, those crystallized and crystalline varieties which are not sufficiently transparent and brilliant for ornamental purposes and which were known to the older mineralogists as " imperfect " corundum. Corundum is superior to emery as an abrasive, because the impurities found in emery are almost entirely absent in corundum; the latter also contains a much larger percentage of crystalline alumina, which is the element in both abrasives that possesses cutting qualities.

The percentage of crystalline alumina found in corundum obtained from the different sections is approximately as follows: Canadian corundum, from 90 to 95 per cent; Georgia corundum, 77 per cent; Brazilian corundum, 76 per cent; India corundum, 73 per cent. In Canadian corundum, iron oxide, which is the most objectionable impurity in emery, is as low as $1\frac{1}{4}$ per cent, as compared with 25 per cent in Naxos emery. Corundum is harder than emery, and, therefore, the abrasive grains will remain sharp longer. The Canadian corundum is mined in Eastern Ontario, where there are very large and practically inexhaustible deposits. The corundum occurs in hexagonal crystals imbedded in felspar, syenite, chlorite, and occasionally in some other non-metallic minerals or gangues. Only the crystals are used, all of the felspar and other gangues being removed by crushing the material and passing it over concentrating jigs and tables, and over magnets and blowers.

COSECANT OF ANGLE. See Functions of Angles.

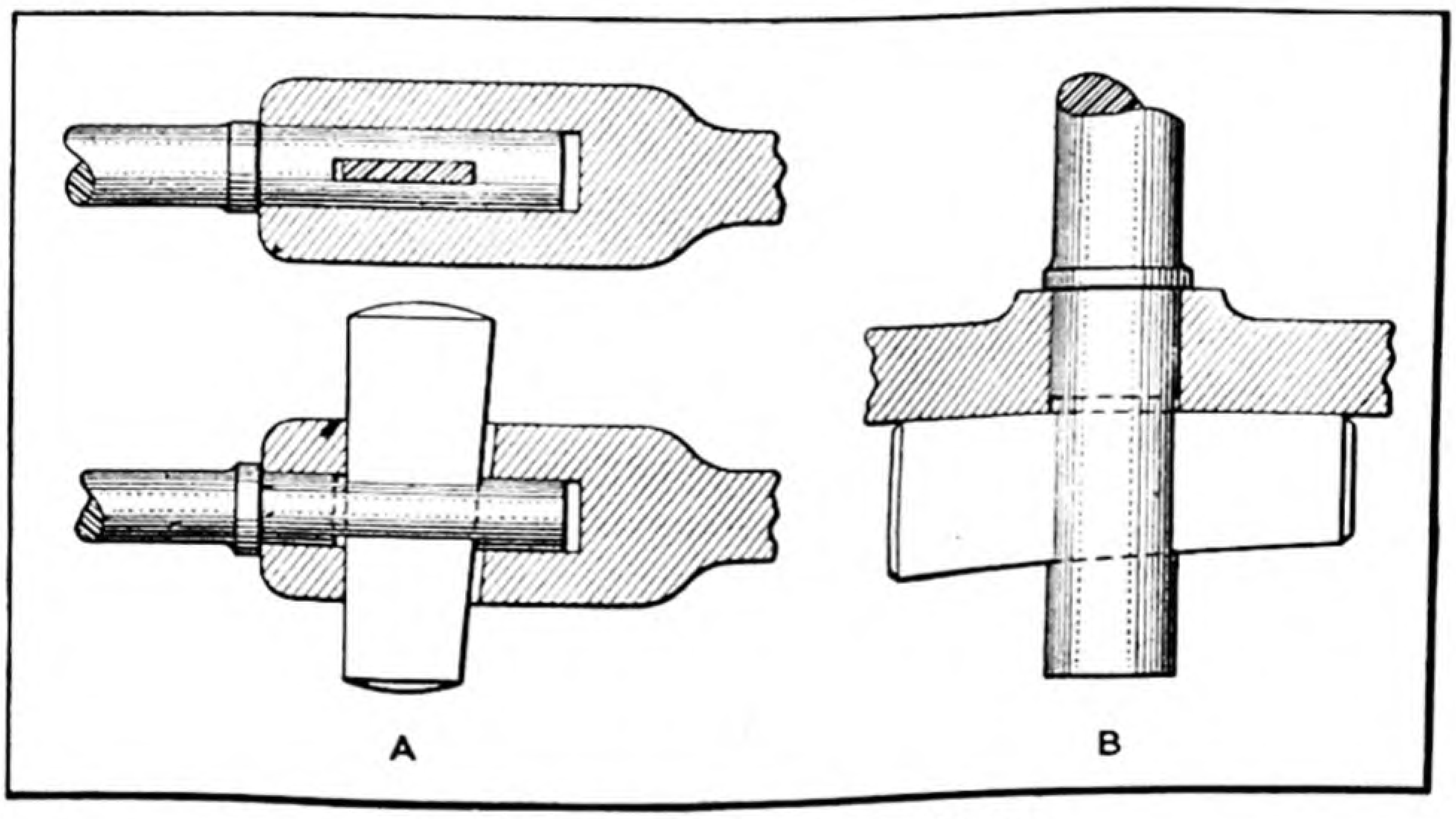
COSINE OF ANGLE. See Functions of Angles; also Law of Sines and Cosines.

COSLETTIZING. Coslettizing is a process for rust-proofing iron and steel. A solution is made from one quart of concentrated phosphoric acid, one quart of water, and one pound of iron filings. This mixture is allowed to stand until the iron is entirely dissolved, and then it is added to water in the proportions of one part of solution to 50 parts of water. The work to be treated is first cleaned as for plating, either by scratch-brushing or by immersion in a muriatic-acid dip, in order to remove any rust that may be present. The parts are suspended in the solution by means of iron wire or hooks, or, in the case of small articles, by placing in iron or earthenware baskets. The solution must be kept close to the boiling point, and the articles are allowed to remain in it for from $\frac{1}{2}$ to 3 hours, depending upon the

nature of the work, a heavy coating being produced in from 2 to 3 hours time. A convenient arrangement for the bath is to make up the solution in an enamel or agateware tank, and heat this tank by placing it in boiling water. After the articles are removed from the solution, they should be allowed to dry in the air, and may then be scratch-brushed on a fine wire wheel, revolving at 600 revolutions per minute, and oiled with linseed or paraffin oil. Another solution is composed of 6 ounces of zinc, 1 pint of phosphoric acid, and 1 pint of water, making a stock solution which is diluted in the proportions of 1 ounce of stock solution to a gallon of water. The method of treating the work is the same as for the other solution.

COTANGENT OF ANGLE. See Functions of Angles.

COTTER. A cotter is a form of key that is used to connect rods, etc., that are subjected either to tension or compression or both. Diagram *A* shows how a cotter is used to hold the valve-stem and valve-rod of an engine together. The cotter is of rectangular section and the edges may



Two Methods of Applying Cotters

be either square or rounded, the latter form being generally used. It is driven transversely through the two members to be held together and the slots are offset somewhat so that the cotter forces the inner rod (in this particular case) against its shoulder. Frequently, a taper fit is employed instead of a cylindrical fit and shoulder, in which case the rod is drawn tightly into the taper hole. In some cases, a cotter simply passes through the end of a rod as shown at *B*.

COTTER FILES. These files are made in both taper and blunt forms, and from pillar sections. They are double-cut, mostly bastard, and principally used for filing the grooves for cotters, keys, etc

COTTER-PINS. The cotter-pin or split pin is used to prevent pins and other parts from working out of their holes, and nuts from unscrewing. After the pin is inserted through a small hole in the part to be kept in place, the ends are spread apart.

COTTON GIN. The cotton gin was invented by Eli Whitney in 1792. This is one of the few great inventions which is due entirely to the work of one man. As the great importance of this invention was generally recognized, many came to see the machine even before patent rights had been granted. The privilege of inspection was denied in order to safeguard the invention, but the building was broken into at night and the machine removed; consequently, its construction was no longer a secret and before Whitney could secure a patent, a number of machines were in successful operation which deviated only slightly from the original design. The result was that Whitney had considerable trouble later in establishing rights to the invention.

COULOMB. The International Electrical Congress, held in Chicago in 1893, recommended the adoption of the *coulomb* as the unit of quantity of electricity, and, by Act of Congress, July 12, 1894, this has been made the legal unit in the United States. A coulomb is the quantity of electricity transmitted by a current of one ampere in one second. It is also equal to the quantity of electricity contained in a condenser with a capacity of one farad, when the same is subject to an electromotive force of one volt. *Micro-coulombs* are used to express small quantities of electricity.

COUNTERBORES. Counterbores are used for enlarging previously drilled holes in such a manner that the bottom of the enlarged hole has a square shoulder. The tool consists of a body part, the end of which is provided with cutting edges, a guide or "pilot" which accurately fits the hole already drilled, and a straight or taper shank by which the counterbore is held and driven.

COUNTER CELLS. Counter cells are used for reducing the charging voltage when charging storage batteries. These cells have two electrodes of pure lead without any active material, but the electrolyte. They give practically constant potentials for all currents passing through them, but no power. The positive electrode of a counter cell is connected to the positive pole of the main cell, so that the potential of the counter cell opposes that of the main cell.

COUNTER-ELECTROMOTIVE FORCE. The counter-electromotive force is the voltage which opposes the flow of current through an armature. There are two sources of pressure in the windings of a motor that is running:
1. The voltage which is impressed on the terminals from an outside source.
2. The voltage which is set up by the windings in cutting the lines of force

or magnetic flux. These two pressures are opposite in direction, and the latter is called the counter-electromotive force, because it opposes the electromotive force impressed across the armature to cause it to turn as a motor. The current that flows is proportional to the difference between the two pressures.

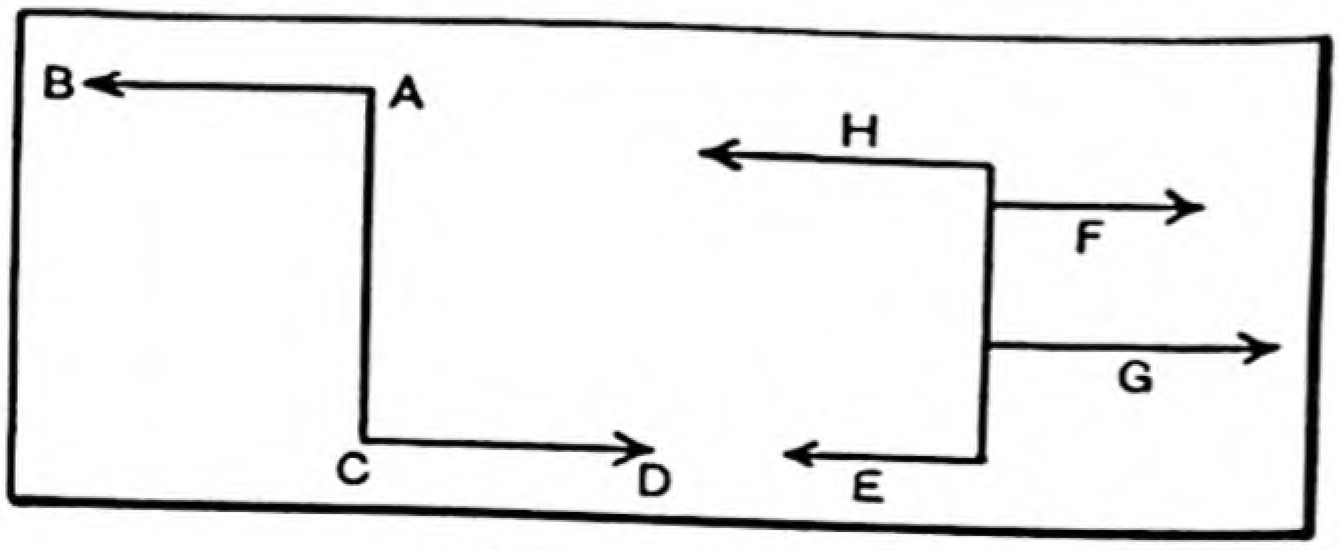
COUNTER-ELECTROMOTIVE-FORCE BOOSTER. An electrical machine used for the charging of storage batteries. It is also known as the *Hubbard booster*.

COUNTERSHAFTS. A countershaft is a short shaft which is driven from a main shaft and serves either to start or stop a machine independently of other machines which may be driven from the same main shaft. With the usual arrangement, the countershaft is driven by a belt and transmits motion to the driven machine by another belt. There are several types of countershafts, some of which are arranged for reversing the direction of rotation, whereas others provide two or more speed changes.

COUNTERSINKING. On some classes of work, screws having heads that are conical on the under side are used. Forming a conical seat for a head of this shape is known as *countersinking*. The operation is similar to counterboring, except that a tool for forming a conical seat has cutting edges which incline to suit the required angle. The pilot form of countersink is used after the hole for the screw-body has been drilled. Countersinks are also used which have a drill of the proper size at the end, instead of a pilot, so that the straight and conical parts of the hole are finished in one operation.

COUNTING BOARD. A tray provided with a large number of semispherical depressions, usually 1000, which is employed for the counting of steel balls. By filling the tray with balls until one ball rests in every depression, the counting of balls in great quantities is easily done, one operator being able to count as many as a million balls a day.

COUPLES OF FORCES. If the forces AB and CD (see illustration) are equal and parallel, but act in opposite directions, then the resultant equals 0, or in other words, the two forces have no resultant and are called a *couple*. A couple tends to produce rotation. The measure of this tendency is called the *moment of the couple*, and is the product of one of the forces multiplied by the distance between the two. As

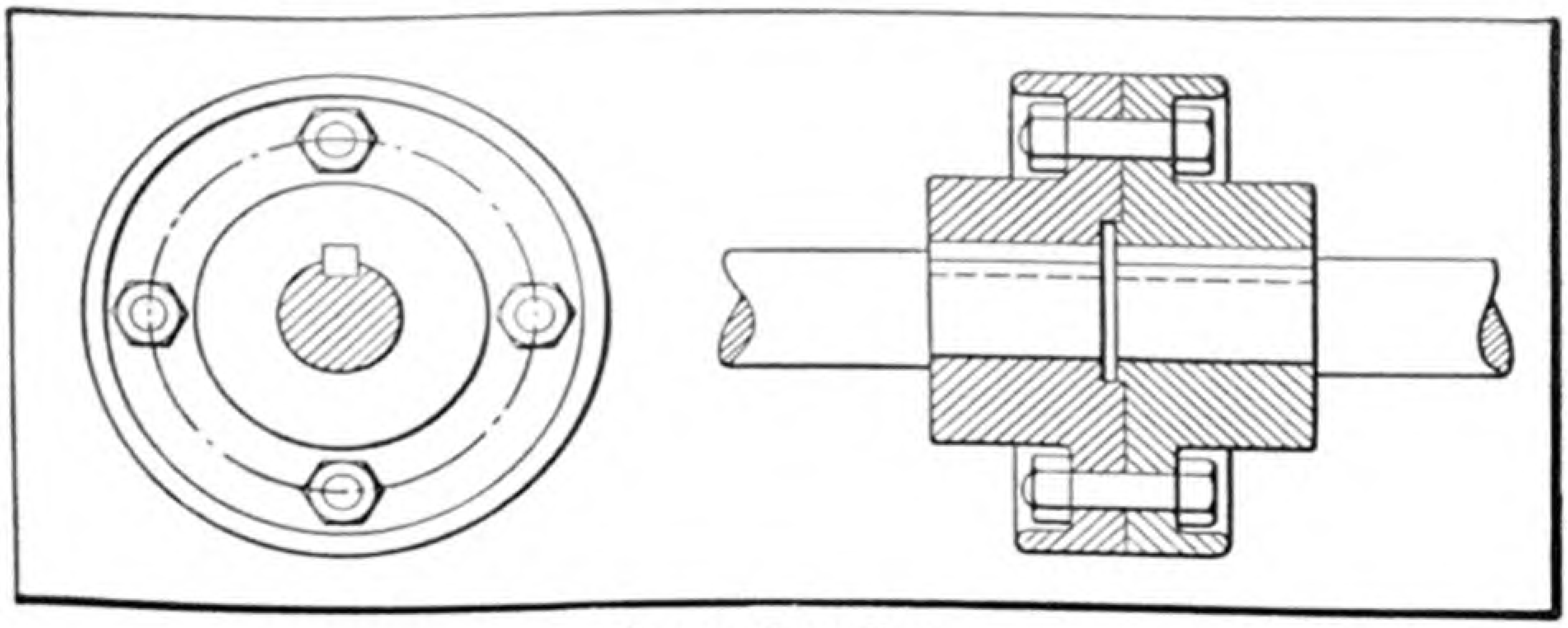


Couples of Forces

a couple has no resultant, no single force can balance it, or counteract the tendency of the couple to produce rotation. To prevent the rotation of a body acted upon by a couple, two other forces are, therefore, required, forming a second couple. The moment of this couple must be equal to the moment of the couple which it balances. In the illustration, E and F form one couple and G and H are the balancing couple. The body on which they act is in equilibrium if the moments of the two couples are equal and tend to rotate the body in opposite directions.

COUPLINGS, PIPE. Couplings are threaded internally for receiving the ends of pipes. They are threaded either with right-hand or with right- and left-hand threads the same as nipples. "Wrought couplings" are commonly used for "wrought pipe."

COUPLINGS, SHAFT. A shaft coupling is a device for fastening together the ends of two shafts, so that the rotary motion of one causes rotary motion of the other. One of the most simple and common forms of coupling is the flange coupling (see illustration). It consists of two flanged



Flange Coupling

sleeves or hubs, each of which is keyed to the end of one of the two shafts to be connected. The sleeves are held together and prevented from rotating relative to each other by bolts through the flanges as indicated. See Flexible Couplings.

COWLES PROCESS. A method for producing aluminum alloys directly from the aluminum ore. This process was used in the early days when aluminum was very expensive, and when commercial alloys could not be produced by using the pure metal. Later, it became the practice to alloy aluminum as a metal with other metals, but there has been a resumption of the direct production of aluminum alloys from the ore. The process consists mainly in mixing bauxite with carbon and the metal to be alloyed, and heating the mixture in an electric furnace. In the presence of the carbon, the aluminum oxide is reduced to aluminum, and this alloys directly with the other metal contained in the furnace. Alloys containing as high as 30 per cent of aluminum have been produced in this manner.

COWPER-COLES PROCESS. The process known by this name is a galvanizing process used for covering iron and steel with metallic zinc. The process is generally known as *sherardizing* from its inventor, Mr. Sherard Cowper-Coles. The principle of the process is explained under the heading, Sherardizing.

CRAB. In an over-head traveling crane, the crab is the carriage moving crosswise of the span along the bridge or girder. It is from this that the load is suspended.

CRACKING PROCESS. The cracking process consists practically in distilling oils at a higher temperature than the normal boiling point. This process, as applied in producing gasoline, may also be defined as a method of splitting up the molecular structure of hydrocarbon molecules by the application of heat supplemented, ordinarily, by pressure which, in modern processes, may be several hundred pounds to the square inch. There are various modifications of the cracking process. These developments have made it possible to secure large amounts of gasoline from the heavy oils, so that the volume of light crude oil is no longer a true indication of the potential gasoline supply. According to a prominent authority, properly cracked gasolines as compared with " straight-run gasoline " obtained from a crude still, have the following advantages: (1) Generally a higher percentage of the lighter and more volatile factions; (2) better starting qualities as applied to internal combustion engines; and (3) non-detonating or " anti-knock " qualities.

When petroleum or crude oil is subjected to ordinary distillation by the application of heat, the lighter products, such as gasoline and kerosene, are distilled off to a temperature of about 300 degrees C. (572 degrees F.). For higher temperatures the hydrocarbons decompose partially so that some light products are produced and distilled along with the heavier products. If the temperature is increased sufficiently, the entire oil residue may be distilled, leaving only a variable amount of residual carbon. This property of all heavy petroleums, which results in decomposing into hydrocarbons of lower molecular weight by heating, is generally known as cracking. There are various cracking processes, such as (1) cracking in the vapor phase under (*a*) atmospheric pressure or under (*b*) high pressures of several hundred pounds to the square inch; (2) cracking in the liquid phase (*a*) with distillation either at atmospheric pressure or under high pressure, or (*b*) without distillation and with high pressure. As to the origin of the cracking process, a United States patent was granted in 1860 to Luther Atwood for the production of light hydrocarbon illuminating oils from heavy oils, paraffins, etc. The first record of pressure distillation appears to be in an English patent granted to James Young in 1865. The extremely high pressure process is covered by a United States patent granted to Benton in 1886.

This patent deals with temperatures ranging from 700 to 1000 degrees F. and pressures as high as 500 pounds per square inch.

CRANES. Cranes may be classified in a number of ways, according to the principal characteristic considered.

Rotary Cranes.—Rotary cranes may be divided into two main subdivisions: *jib* and *pillar* cranes. The *jib crane* consists mainly of a post or pillar from which extends a horizontal arm or jib. On this jib, a crab or trolley moves in a radial direction. *Pillar cranes* are provided with a pivot at the lower end of the column or post only, and are supported entirely from the foundation. These cranes, as a rule, are not provided with a jib and trolley, and, hence, the load is rotated in a horizontal direction along the periphery of a circle, but has no radial movement. A special type known as *pillar jib crane* is identical with the regular type of pillar crane in that it is pivoted and supported entirely at the foundation, but is provided with a jib on which a trolley moves, so that the load can be moved both in a radial and circular direction. Pillar cranes having a rotary motion only, but no trolley motion, are frequently known as *swing cranes*. The same name is applied to jib cranes if they are not provided with a trolley motion. Pillar cranes which are mounted on wheels, and so arranged that they can travel longitudinally upon rails, are known as *portable cranes* or *walking cranes*. When these portable cranes are provided with a steam engine capable of propelling them along the rails, they are known as *locomotive cranes*. In this type, steam power is also used for hoisting and moving the load.

Rectilinear Cranes. — The most common of all rectilinear cranes is the *overhead traveling crane* in which there is, in addition to the lifting motion, provision for two horizontal movements at right angles to one another, so that the load can be deposited at any point within the rectangle covered by the movement of the crane. Traveling cranes consist of a bridge generally spanning the bay of a shop or foundry, which moves longitudinally on overhead tracks provided at the end of the bridge, giving the straight-line motion in one direction. On this bridge is mounted a trolley or crab which moves transversely along the bridge, thus giving the straight-line motion in the other direction. A *gantry crane* is similar to the overhead traveling crane except that the overhead bridge is here carried at each end by a trestle which travels on longitudinal tracks on the ground. A trolley is placed on the bridge to give the transverse motion. *Bridge cranes* have a horizontal straight-line movement in one direction only, the bridge being in a fixed position, while a trolley moves along the bridge. *Tram cranes* also have a movement in one direction only, except that in this case a very short bridge without a trolley is provided, which travels longitudinally on overhead rails.

CRANKSHAFT CHEEK-TURNING LATHE. This type of machine is used for turning simultaneously all of the cheeks of automobile engine crank-

shafts. It is equipped with a number of rocker arms corresponding to the number of crankshaft cheeks, and each rocker arm controls a tool held in a segment-shaped toolholder which is shifted to automatically maint:in the proper cutting angle.

CRANKSHAFT COLD SAW. The crankshaft cold saw cutting-off machine is arranged for carrying two saws upon a single arbor so that two cuts may be made simultaneously when sawing out the web of a crank. These machines are built in various designs and may be used for many other operations, such as sawing out the ends of locomotive main-rods of the open-end type, and for similar work.

CRANKSHAFT GRINDING. The modern method of finishing crankshaft bearings is by grinding. The bearings may either be rough-turned in a lathe equipped for this purpose, and then be finished by grinding, or they may be ground directly from the rough drop-forging. The practice in different shops varies; ordinarily, whether or not crankshafts are rough-turned prior to grinding depends upon their size and the amount of stock to be removed. One method of finishing the pins is to use a wheel that is equal in width to the width of the bearing, so that the entire pin can be finished by feeding the wheel straight in, and without a traversing movement. Grinding machines which are used exclusively for grinding crankshafts of the type used in motors for automobiles, launches, etc., are equipped with special work-holding fixtures so arranged that the different crankpins may be aligned with the axis of the grinding machine spindle.

CREOSOTING PROCESSES. Different methods are used for applying creosotes or other preservatives to wood poles. In the closed-tank method, the poles are placed in a large tank and steamed for from five to eight hours; a partial vacuum is then applied, after which the creosote is run in at a temperature of from 140 to 175 degrees F. under sufficient pressure to obtain the amount of absorption desired. In the open-tank creosoting process, usually applied to the butts of poles only, the poles are placed in an inclined or vertical position with the butts immersed in the creosote, which is kept at a temperature of about 220 degrees F., for about six hours. The bath is then allowed to cool, and after it has fallen to 110 degrees F., the poles may be removed; or the poles may be changed to a cold bath (110 to 150 degrees F.) and allowed to remain for several hours. During the period of the warm bath, the air and moisture in the cells of the wood are driven out, and during the period of cooling off, the creosote enters the cells and remains there. By the open-tank method it is not possible to impregnate the wood to the same depth as with the closed-tank or pressure method. The treatment is, however, worth while, and the United States Forest Service estimates the useful life to be approximately twenty years for chestnut and western cedar,

twenty-two years for northern white cedar, and twenty years for pine in the dry climate of western United States. In this connection, it should be mentioned that in poles with treated butts, it is the upper part of the poles that will decay first and govern the life of the pole. In the so-called "brush treatment," the preservative is applied with a brush. This practice is sometimes modified by pouring or spraying the preservative on the poles.

CREST OF THREAD. The name "crest" has been applied to the curved or rounded top of a Whitworth thread.

CREST VOLTMETER. This is a voltmeter depending for its indications upon the crest, that is, the maximum value of the voltage of the system to which it is connected.

CRITICAL SPEED. If a body or disk mounted upon a shaft rotates about it, the center of gravity of the body or disk must be at the center of the shaft, if a perfect running balance is to be obtained. In most cases, however, the center of gravity of the disk will be slightly removed from the center of the shaft, owing to the difficulty of perfect balancing. Now, if the shaft and disk are rotated, the centrifugal force generated by the heavier side will be greater than that generated by the lighter side geometrically opposite to it, and the shaft will deflect toward the heavier side, causing the center of the disk to rotate in a small circle. These conditions hold true up to a comparatively high speed; but a speed is eventually reached when momentarily there will be excessive vibration, and then the parts will run quietly again. The speed at which this occurs is called the *critical speed* of the wheel, and the phenomenon itself is called the *settling* of the wheel. The explanation of the settling is that at this speed the axis of rotation changes, and the wheel and shaft, instead of rotating about their geometrical center, begin to rotate about an axis through their center of gravity. The shaft itself is then deflected so that for every revolution its geometrical center traces a circle around the center of gravity of the rotating mass.

A shaft carrying a distributed load or a number of loads may have a series of critical speeds, but ordinarily it is the first critical speed that is of importance. The critical speeds depend upon the location and magnitude of the load or loads carried by the shaft, the shaft diameter and length, and the kind of supporting bearings. To insure safe operation, the maximum speed of a machine ordinarily should not exceed 80 per cent of the first critical speed. While it is possible to run a machine close to a critical speed, greater precision is required in the alignment and play of the bearings, the balance, and the construction generally; moreover, if the running speed is too close to the critical speed, vibration troubles may be encountered later due to looseness or play which may develop.

CRITICAL TEMPERATURES. The temperatures at which certain changes in the chemical condition of tool steel take place, during both heating and cooling, are referred to as the decalescence and recalescence or critical points, and the effect of these molecular changes is as follows: When a piece of steel is heated, it reaches a certain point at which it continues to absorb heat without appreciably rising in temperature, although its immediate surroundings may be hotter than the steel. This is the *decalescence* point. Similarly, steel cooling slowly from a high heat will, at a certain temperature, actually increase in temperature, although its surroundings may be colder. This takes place at the *recalescence* point. The recalescence point is lower than the decalescence point by anywhere from 85 to 215 degrees F., and the lower of these points does not manifest itself unless the higher one has first been fully passed. These critical points have a direct relation to the hardening of steel. Unless a temperature sufficient to reach the decalescence point is obtained, no hardening action can take place; and unless the steel is cooled suddenly before it reaches the recalescence point, no hardening can take place. The critical points vary for different kinds of steel and must be determined by tests in each case. It is the variation in the critical points that makes it necessary to heat different steels to different temperatures, for hardening.

CROCHET FILE. Crochet files are rounding on both edges and, in a lengthwise direction, taper to a small point.

CRODON. Crodon is a trade name for a chromium plate that is claimed to be ten times as hard as nickel plate and three times as hard as cold-drawn steel. On the hardness scale, it is listed at 9 as compared to the diamond at 10. This hardness is particularly useful where resistance to rubbing action is required.

"Crodon" is not oxidized below 700 degrees F., and will protect steel from scaling at 1500 degrees F. and above. This property is being utilized in pyrometer parts, soot cleaner elements, oil burner parts, oil cracking equipment, and thermostat parts. "Crodon" is not affected by organic acids, salt water atmosphere, nitric acid, or sulphur compounds. This resistance to sulphur has proved useful in rubber molds and on oil equipment in contact with sulphur bearing oils at high temperatures. See Chromium Plating.

CROSS. A pipe fitting with four branches arranged in pairs, each pair on one axis, and the axes at right angles. When the outlets are otherwise arranged the fittings are branch pipes or specials.

CROSS-COMPOUND ENGINES. Cross-compound engines consist of two complete engines, except for the shaft and flywheel, which are common to both. The engine is so piped that the high-pressure cylinder exhausts

into the low-pressure through a receiver. The use of this type is confined principally to cases where large amounts of power are required and where there is ample floor space, as in rolling mills and similar locations.

CROSS-CUT FILE. A type having one round edge with sides tapered toward the opposite edge. A cross-cut file is single-cut, the same as a mill bastard file of the same size.

CROSSING FILE. Crossing or cross files have a double oval section, one side being shaped like a half-round file and the other like a cabinet file. The cut is either bastard, second-cut, or smooth.

CROSS-OVER. A small fitting with a double offset, or shaped like the letter U with the ends turned out. It is only made in small sizes and used to pass the flow of one pipe past another when the pipes are in the same plane.

CROSS-SECTION PAPER. Cross-section paper has horizontal and vertical ruled lines spaced the same distance apart. When this ruling is so made that the horizontal spaces are much less than the vertical, the paper is properly called *profile paper*. Cross-section paper is used for making sketches, diagrams, etc., and for free-hand work; the ruling is of great assistance in properly proportioning the parts. It is also largely used in the plotting of graphic charts and similar work. Cross-section paper is obtainable with a ruling of either 10 or 16 lines to the inch, and also with millimeter ruling. There is also cross-section paper made with 8 and 12 lines to the inch.

CROSS VALVE. (1) A valve fitted on a transverse pipe so as to open communication at will between two parallel lines of piping. This type is much used in connection with oil and water pumping arrangements, especially on board ship. (2) Usually considered as an angle valve with a back outlet in the same plane as the other two openings.

CROTCH. A pipe fitting that has the general shape of the letter Y. Caution should be exercised not to confuse the crotch and a Y-fitting or wye.

CROWFOOT CELL. A primary cell or battery of the same type as the *Daniell cell*. The name is derived from the fact that the zinc anode has a number of projecting arms, making it resemble the foot of a bird.

CROWN GEAR. In bevel gearing, when the pitch-cone angle of one of the gears is 90 degrees, this gear is called a *crown gear*. In this case, there is, properly speaking, no pitch cone, but rather a pitch plane. The crown gear of bevel gearing is equivalent to the rack of spur gearing.

CROWN OF PULLEY. See Pulley Crown.

CRUCIBLE. Crucibles are pots used for melting small amounts of various metals. Their principal use in the iron and steel industry is in the

manufacture of crucible steel, when they generally have a capacity of from 75 to 200 pounds, the larger sizes being used only when mechanical lifting means are available. The most extensive use for crucibles, however, is in the brass industries. In many English and some American plants, the crucibles are made of a high quality of clay mixed with about 5 per cent of powdered coke. They are then known as *clay crucibles* or "white pots," but the care required in the handling of these crucibles has brought them into disfavor with most American manufacturers, who use graphite crucibles instead. Graphite crucibles can be recharged while cold, tested for thickness and cracks before each charging, and will stand rougher handling and more heats than the clay pots.

CRUCIBLE FURNACE. A crucible furnace is one in which metal that is to be melted is contained in crucibles placed in the furnace. The furnace may be heated by coal, coke, gas, or oil. The use of gas or oil lessens the labor required and permits better control of the heat; it also permits the heat to be localized, when desired; but carelessness in handling these fuels is more likely to destroy the crucibles than in the case of coal or coke.

CRUCIBLE STEEL. Crucible steel, also known as *tool steel, high-carbon steel*, and, in England, sometimes as *pot steel*, is made by using high-grade, low-phosphorus wrought iron and adding carbon to it. The name *crucible steel* is derived from the fact that in the final process of making this steel, it is melted in crucibles. Small pieces of wrought iron are put directly into an air-tight crucible containing the proper amount of powdered charcoal, and melted down. In this way, the proper amount of carbon is added in order to form the high-carbon steel desired. The process was first developed by Robert Huntsman, in England, about 1740. Wrought-iron is always used in the making of crucible steel of the best grade; but cheaper grades of steel are sometimes made by using Bessemer and open-hearth soft steels; this product, however, is not as good as when wrought iron is used.

CRUDE OIL. See Petroleum.

CRYSTALLOGRAPHY. See Metallography.

CRYSTOLON. The abrasive known as *crystolon* is an electric furnace product, consisting of carbide of silicon in crystalline formation. Coke, sand, sawdust, and salt are used in its manufacture. These materials, after being carefully mixed together, are heated to a temperature ranging between 1820 and 2250 degrees C. (3308 and 4082 degrees F.). Crystolon is especially adapted for polishing and grinding such metals as cast iron, chilled iron, brass, and, in general, all materials of low tensile strength.

CUBE ROOT. The cube root of a given number is the number which, if repeated as a factor three times, would give a product equal to the given

number. If the given number is 125, the cube root is 5, because $5 \times 5 \times 5 = 125$.

CUBIC EQUATION. See Equations.

CUBIC MEASURE. 1 cubic yard = 27 cubic feet; 1 cubic foot = 1728 cubic inches; the following measures are also used for wood and masonry; 1 cord of wood = $4 \times 4 \times 8$ feet = 128 cubic feet; 1 perch of masonry = $16\frac{1}{2} \times 1\frac{1}{2} \times 1$ foot = $24\frac{3}{4}$ cubic feet.

CULM COAL. Finely pulverized coal which passes through a screen of $\frac{3}{16}$ inch mesh. It is often used for power plant purposes. Culm coal is also known simply as *culm*, and also as *slack of screenings*.

CUPOLA BESSEMER ELECTRIC PROCESS. One method of producing the "white iron" used in making malleable castings is known as the "cupola Bessemer electric process." Briefly, the iron is melted in the ordinary cupola, blown in a Bessemer converter to obtain the proper analysis, and reheated in an electric furnace preparatory to casting. This system can be used to advantage in large plants having a central melting room. The grade of malleable iron produced is excellent.

CUPOLA JACK POLISHING MACHINE. A type of polishing machine known as the "cupola jack," has been extensively used, especially in the cutlery industry. The cupola jack frame consists of a cast-iron base with two cast-iron upright columns, connected by a brace at the middle. The upper end of each column is arranged to hold a removable hard-wood block in a horizontal position, with the end of the grain against the end of the shaft, and fastened in place by a set-screw. The spindle and arbor hole of the wheel are both tapered, and the polishing wheel is driven on the spindle with a tight fit. The ends of the spindle are tapered down to points, and fitted into countersunk depressions cut into the ends of the hard-wood blocks which constitute the bearings.

CUPOLAS AND AIR FURNACES. Two kinds of furnaces are used for melting iron preparatory to making castings, namely, cupola furnaces or "cupolas," as they are commonly called, and reverberatory or air furnaces. The cupola furnace is the most common, and is more simple in operation. In this kind of furnace, the iron and the fuel are charged together, while, in the air furnace, they are charged in separate compartments. The latter type of furnace is more frequently used in the making of malleable-iron castings. The cupola type of furnace is used in nearly all cases except when it is necessary to melt large bodies of iron, or when very large castings are to be made; the reverberatory type is preferable in the latter case, because a large body of metal can be obtained at one tapping. Ordinarily, some flux, such as limestone, is placed in the cupola when charging. This flux melts

and serves the double function of first forming a slag by the combination of the lime with the silica from the charge, thus removing the silica, and also forming a protective covering for the bath of molten metal in the well of the cupola. In determining upon the various mixtures for producing different kinds of iron in a cupola, it is necessary to consider the quality and quantity of pig iron and scrap iron of various kinds, as well as the fuel and the flux that may be used.

CUPRO-NICKEL. Cupro-nickel is an alloy which is especially used for blading and binding strips in steam turbines. It consists of from 79 to 81 per cent of copper, the remainder being nickel, with a permissible iron content not to exceed 0.75 per cent. These percentages agree with the requirements of the United States Navy Department specifications.

CURLING AND WIRING DIES. Curling and wiring dies are used extensively for curling over or "wiring" the edges of pails, pans, and many other similar articles made of tinware, brass, copper, etc. What are known as *curling dies* are also used, to some extent, for rolling small tubular parts or forming cylindrical edges on hinges, etc. The dies used in conjunction with tinware are commonly called *wiring dies*, because of their use for curling the edges of circular shaped articles around a wire, thus forming a strong, smooth edge. In many cases, the edges are curled without inserting a wire; this operation is usually referred to as "false" or "imitation" wiring, and these dies are also known as wiring dies. Curling or wiring dies for tapering parts such as milk pans, etc., have a punch which is composed of six or eight segments instead of being solid, so that it can contract when entering the tapered part.

CURRENCY COINING PRESSURES. See Coining Pressures.

CUSTER PROCESS. A method of producing castings in permanent molds. See Casting in Permanent Molds.

CUT-OFF. The cut-off is the point in the stroke of a steam engine at which the admission valve closes the port and the expansion of steam begins.

CUTTER GRINDER. Cutter grinding is often done on cylindrical grinding machines of the universal type, and even in the lathe, by the use of a grinding attachment, especially in small shops, but it is preferable to use a machine designed especially for this class of work. These special machines are so arranged that they may be used for grinding plain cylindrical cutters, angular cutters, end-mills, side-mills, formed cutters, reamers, circular forming tools, saws for cutting-off machines, and a variety of other tools. While the universal tool- and cutter-grinders made by different manufacturers vary more or less as to details, they are similar in their general arrangement and operate on the same general principle.

Tooth-rest for Cutter Grinding. — A tooth-rest is used to support a cutter while grinding the teeth. For grinding a cylindrical cutter having helical or "spiral" teeth, the tooth-rest must remain in a fixed position relative to the grinding wheel. The tooth being ground will then slide over the tooth-rest, thus causing the cutter to turn as it moves longitudinally, so that the edge of the helical tooth is ground to a uniform distance from the center, throughout its length. For grinding a straight-fluted cutter, it is also preferable to have the tooth-rest in a fixed position relative to the wheel, unless the cutter is quite narrow, because any warping of the cutter in hardening will result in inaccurate grinding, if the tooth-rest moves with the work. The tooth-rest should be placed as close to the cutting edge of the cutter as is practicable, and bear against the *face* of the tooth being ground.

"CUTTING DOWN." When parts are finished by buffing the term "cutting down" is applied to the operation of removing slight imperfections left either by previous polishing or by rolling, stamping, etc. The relatively high finish obtained by cutting down is refined by "coloring" which gives a high luster either preparatory to plating or on surfaces after plating.

CUTTING METALS WITH OXIDIZING FLAME. The principle of oxy-acetylene or oxy-hydrogen metal cutting is based on the fact that, if a piece of steel or iron is brought to a red heat and a jet of pure oxygen is turned against it, the metal will be oxidized or will burn. The ordinary cutting torch consists of a heating jet using oxygen and acetylene, oxygen and hydrogen, or, in fact, any other gas which, when combined with oxygen, will produce sufficient heat. By the use of this heating jet, the metal is first brought to a sufficiently high temperature, and an auxiliary jet of pure oxygen is then turned onto the red-hot metal, when the action just referred to takes place.

Thickness of Metal that can be Cut. — The maximum thickness of metal that can be cut by high-temperature flames depends largely upon the gases used and the pressure of the oxygen; the thicker the material, the higher the pressure required. When using the oxy-acetylene flame, it is practicable to cut steel up to 7 or 8 inches in thickness, whereas, with the oxy-hydrogen flame, the thickness can be increased to 20 or 24 inches. The oxy-hydrogen flame will cut thicker material principally because it is longer than the oxy-acetylene flame and can penetrate to the full depth of the cut. A mechanically-guided torch will cut thick material more satisfactorily than a hand-guided torch. With any flame, the cut is less accurate and the kerf wider, as the thickness of the metal increases. When cutting light material, the kerf might not be over $\frac{1}{16}$ inch wide, whereas, for heavy stock, it might be $\frac{1}{4}$ or $\frac{3}{8}$ inch wide.

Use of Illuminating Gas. — One of the large manufacturers of electrical machinery has used illuminating gas instead of acetylene or hydrogen, in

connection with oxygen, in order to reduce the costs for certain metal-cutting operations. A special oxy-illuminating gas torch was developed and it proved successful for cutting risers in the steel foundry varying in thickness from 1 to 20 inches. Illuminating gas has also been used in conjunction with machines for cutting various shapes from steel plates. It is claimed that the illuminating gas is not only cheaper for machine cutting than either hydrogen or acetylene, but that the speed of cutting after once starting is approximately equal for all gases. The advantages claimed for the use of illuminating gas are (1) availability; (2) elimination of delays and handling of tanks; (3) low cost; (4) safety; and (5) chemical and physical properties that permit its use in a torch equipped with a superheater, thus effecting marked economies in the amount of oxygen required by the cutting jet.

Cutting Cast Iron. — The cutting of cast iron with the oxy-acetylene torch is practicable although it cannot be cut as readily as steel. The ease of cutting seems to depend largely on the physical character of the cast iron, very soft cast iron being more difficult to cut than harder varieties. The cost is much higher than that for cutting the same thickness of steel, because of the larger pre-heating flame necessary and the larger oxygen consumption. In spite of this, however, this method is economical in many cases. The slag from a cast iron cut contains considerable melted cast iron, while in the case of steel, the slag is practically free from particles of the metal. This indicates that cast iron cutting is partly a melting operation. Increased speed and decreased cost can often be obtained by feeding a steel rod, about $\frac{1}{4}$ inch in diameter, into the top of the cut, just beneath the torch tip. This furnishes a large amount of slag which flows over the face of the cut and increases the temperature of the cast iron. Special tips are used owing to the large amount of heat and of oxygen required.

CUTTING-OFF MACHINES. In general, any machine which is designed exclusively for cutting either bar stock or structural steel may be considered as a *cutting-off machine*, but this term is usually applied by manufacturers to those machines which rotate the stock and sever it by means of a cutting-off or parting tool; machines which utilize a revolving saw for severing the material are commonly listed as *cold-saw cutting-off machines*, or simply as cold saws. The term " cold " is used in this connection to indicate that the machine is intended for cutting unheated stock. Among other machines used for cutting off stock, which may properly be inserted under the general classification of cutting-off machines, are hacksaw machines, metal-cutting band saws, abrasive wheel cutting-off machines, and the friction saw. See Cold-Saw Cutting-off Machines.

CUTTING OILS AND COMPOUNDS. Oil or cutting compound is delivered to a metal-cutting tool in order to increase production, to give longer life to the tool, and in some cases to secure a better finish on the work.

The functions of an oil or cutting compound may be presented under five heads: (1) To cool the work and cutter. (2) To wash away chips. (3) To lubricate the bearing formed between the chip and lip of the cutting tool. (4) To enable the cutting tool to produce a good finish. (5) To protect the finished product from rust and corrosion.

The cooling action is the most important function. During the performance of any machining operation generation of heat is due to friction between the tool and work, and to distortion of the chips. This results in raising the temperature of both the cutting tool and the work; and if provision is not made for the removal of this heat, the temperature may become so excessive that the cutting edge of the tool breaks down. Another important consideration is the possibility of having the work raised in temperature so that it expands considerably during the machining operation, and while the tools may continue to produce parts of the required size when measured at this high temperature, the work will contract on cooling so that it will be under size.

Classes of Oils and Compounds. — A great variety of oils and cutting compounds are used for lubricating and cooling metal-cutting tools; these may be roughly subdivided into two general classes. The first consists of either pure lard oil, sperm oil, etc.; a mixture of lard oil with certain mineral and vegetable oils; and pure mineral oil or pure vegetable oil. Pure lard oil, a mixture of lard and mineral oil, and pure mineral oil are the most commonly used members of this class. The second class consists of the so-called cutting compounds which are water emulsions of soap, oil and other ingredients to prevent the water from causing rust or corrosion and to afford some lubricating action. Originally a saturated water solution of soda was used for this purpose, but this had little more than a cooling effect, and it has now been largely replaced by the so-called soluble oil compounds, which offer a certain degree of lubricating action in addition to their cooling effect. Most of these so-called solutions are really emulsions in which oil is suspended in the water.

Protection from Rust and Corrosion. — As regards protection of the finished product from rust and corrosion, it is well known that good cutting oils will prevent rusting of parts made from iron or steel, but cutting oils containing lard oil with too high a percentage of free fatty acid will cause verdigris to form on brass parts. Mixtures containing vegetable oils do not have this injurious action, but they are likely to give trouble through gumming the bearings of automatic machines; this is particularly marked in oil mixtures containing highly blown rape or cottonseed oil. Cutting compounds made by dissolving soluble oils in water may give trouble by causing iron and steel products to rust, provided the solution is too weak or contains free acid; poor cutting compounds may also give trouble by gumming.

CYANIDE. Cyanide is a salt of prussic or hydrocyanic acid. The most important of the cyanides commercially is *potassium cyanide*, which is used in the "cyanide process" of gold extraction, and in the mechanical industries as a heating bath for hardening steel, and as a means for casehardening. Cyanide of potassium as a heating bath for heating steel cutting tools, dies, etc., is preferred, in practice, by many to lead heating baths. Cyanide of potassium must be used carefully, because it is a violent poison. The fumes are very injurious and the crucible containing it must be covered with a hood connecting with a chimney or ventilating shaft. The bath is extensively used for hardening when an ornamental color effect is desired on the hardened parts.

CYANIDE COLORING OF STEEL. In using cyanide to color hardened steel, the work is immersed in the bath, brought up to its hardening temperature, and then transferred to a water bath for quenching. At the moment of quenching, the cyanide causes the quenching bath to become violently agitated as a result of the rapid transformation of small quantities of water to steam; this steam and the air drawn into the water by the agitation, partially oxidizes the steel in spots, giving the variegated colors, which are simply intensified tempering colors. While in the cyanide bath the steel is protected from the oxidizing effect of the air and it is also protected during its transfer to the quenching bath by a liquid film of cyanide which adheres to the steel and thus prevents the air from coming in contact with the work. The use of a cyanide pot for complete immersion of the work is more satisfactory than the method of sprinkling powdered cyanide on the work while it is being heated. Fair results can often be secured by the latter method, but more often the cyanide burns off and the steel is oxidized beyond the temper colors of, say, 650 degrees F. To increase the mosaic effect and obtain brighter colors, hardeners effectively employ either or both of the following methods: (1) Pass the hot steel through a water spray when transferring from the cyanide to the quenching bath. (2) Have a stream of air bubbling through the water in the quenching tank.

CYANIDE HARDENING. When low-carbon steel requires a very hard outer surface but does not need high shock-resisting qualities, the cyanide hardening process may be employed to produce what is known as superficial hardness. This superficial hardening is the result of carburizing a very thin outer skin which may be only a few thousandths inch thick. The preferable method of cyanide hardening is by immersing the steel in a bath of liquid potassium cyanide or some other mixture containing cyanogen as a base. This carburizing process is, of course, followed by quenching. Another method of cyanide hardening is to sprinkle over the surface of the steel a pulverized cyanide salt which is melted as the steel is heated to the proper temperature. Referring to the first method, which is conducive to greater

uniformity in carburizing as well as incrassed efficiency, the potassium cyanide salt is melted in a pot furnace and the temperature of the molten bath should be slightly over the upper critical range of the salt — say 1550 to 1600 degrees F. The steel ordinarily is immersed for 10 or 15 minutes and it is quenched usually in lime water to neutralize the cyanide remaining on the steel. The pot furnace used should be equipped with a hood for carrying off the fumes as cyanogen compounds are deadly poisonous.

CYANIDE-OF-POTASSIUM BATH. Many steel hardeners prefer cyanide of potassium to lead, for heating steel cutting tools, dies, etc. When cyanide is used, the parts should be suspended from the side of the crucible by means of wires or wire cloth baskets, to prevent them from sinking to the bottom. Steel will not sink in a lead bath, as lead has a higher specific gravity than steel. Cyanide of potassium should be carefully used, as it is a violent poison. The fumes are very injurious, and the crucible should be enclosed with a hood connecting with a chimney or ventilating shaft. This bath is extensively used for hardening in gun shops, in order to harden parts and at the same time secure ornamental color effects.

CYCLE, ALTERNATING CURRENT. "Cycle," as applied to alternating current, refers to that period of time in which the current builds up from zero to its maximum, then drops gradually back to zero, and passes through the same increase and decrease in the opposite direction. Thus there are two alternations for each cycle. By the "number of cycles," that is, 60, 50, or 25, is meant the number of complete cycles per second. In other words, for a 60-cycle line there are $60 \times 60 \times 2 = 7200$ alternations per minute.

CYCLE ENGINEERS' THREAD. The standard thread which was adopted by the Cycle Engineers Institute of Great Britain is made with a 60-degree angle and rounded at the top and bottom, the depth of the thread being equal to 0.5327 times the pitch, and the radius of the round at top and bottom being equal to one-sixth of the pitch.

CYCLES, INTERNAL COMBUSTION ENGINES. Engines of the internal combustion type or those which derive energy from gas, gasoline and other oils, may be divided into two general classes. One class includes engines which operate on the *four-stroke cycle* or the Otto cycle, and the other class includes the *two-stroke cycle* engines. The four-stroke cycle consists of a suction stroke which serves to draw the mixture of air and fuel into the cylinder; a compression stroke during which the charge of air and fuel is compressed into the clearance space; the expansion stroke which follows the ignition of the charge or the explosion of the gaseous mixture; and finally the exhaust stroke which expels the burned charge from the cylinder. Since four piston strokes are thus required to complete one

cycle, there is one explosion during two revolutions of the crankshaft; consequently, the flywheel is depended upon to store enough energy to keep the engine moving at a fairly uniform rate during the complete cycle. The two-stroke cycle engines of the ordinary type are so designed that an explosion occurs every revolution of the crank.

CYCLOID. The cycloid is a geometrical curve which is produced by a point located on the periphery of a circle when the circle rolls along a straight line. A curve known as an *epicycloid* is formed by a point on the circumference of a circle which rolls on the outside of another circle. A *hypocycloid* is produced by a point on the circumference of a circle which rolls along the inside of the circumference of a larger circle.

CYCLOIDAL GEAR TEETH. When the outline of gear teeth is formed by an epicycloid above the pitch circle and by a hypocycloid below the pitch circle, the gear teeth so formed are generally known as *cycloidal gear teeth.* The most important point in favor of the cycloidal system of gearing is the freedom from interference of the teeth, but this advantage is considerably modified by the fact that, in order that cycloidal gears shall run properly together, the pitch circle of the two gears must tangent each other; that is, the center distance between the two gears must be very accurate. With involute gears, the distance between the centers may be varied somewhat without affecting the smoothness of the action. Cycloidal gear teeth are not used to the extent now that they were formerly employed. Cast gears were in the past always made with this system of teeth, and many are still so made, but in cut gearing, and for a large proportion of cast gearing, the involute system has replaced the cycloidal.

CYLINDER-BORING MACHINE CLASSIFICATION. The general methods of boring and finishing cylinders differ in regard to the method of presenting the tool to the work and of obtaining the necessary rotating and feeding movements. For instance, the tool may be held stationary except for the feeding movement, while the cylinder is revolved, or this order may be reversed. In some cases, the tool is given both a rotating and feeding movement, the exact arrangement depending upon the type or design of the machine. All cylinder boring machines may be included in one of three general classes designated as (1) machines designed exclusively for cylinder boring; (2) machines which may be adapted for cylinder boring but are intended for other operations as well; (3) portable machines or boring-bars which are applied to the cylinder to be bored. The first class includes both horizontal and vertical designs which vary considerably in regard to the general arrangement of the various details. The second class of machines mentioned which are not designed primarily for cylinder boring, but which are adaptable to it, includes such machines as engine lathes, turret

lathes, and horizontal and vertical boring machines. The third class includes the various forms of portable boring-bars which have their own feeding mechanism and (with the exception of hand-operated tools for truing small cylinders) are designed for a power drive, either by belt or by a direct-connected motor. The cylinder boring machines of vertical design have been extensively used for automobile engine cylinders.

CYLINDER-BORING MACHINES, HORIZONTAL. Machines of this class are designed more particularly for comparatively large cylinders such as are used on locomotives, stationary steam engines, pumps, etc., and they are generally found in shops where such cylinders must be bored continually and the expense of a special cylinder boring machine is warranted. Horizontal cylinder boring machines of the types commonly used, resemble, in general outline, an ordinary horizontal boring machine, except that they are usually more massive in construction. Some cylinder boring machines are equipped with an adjustable work table, whereas others have a fixed table that is integral with the base. Boring machines of this class have exceptionally heavy boring-bars, and facing arms are attached to the bar on each side of the cylinder for facing the flanges. Some cylinder boring machines have a boring-bar which is given a longitudinal feeding movement and have the cutter head fixed to it; there is another type of machine in which the cutter head travels along the boring-bar, while the latter is revolved in a fixed longitudinal position.

CYLINDER-BORING MACHINES, VERTICAL. In automobile and other factories where a great many gasoline engine cylinders are required, multiple-spindle boring machines of the vertical type are commonly used. Machines of this kind are designed especially for boring operations, and are equipped with spindles which revolve instead of having a revolving table like a vertical boring mill. The lower end of each spindle has attached to it a cutter-head and, on a typical machine, the boring is done by feeding the table and casting vertically. This feeding movement is effected by power and is disengaged automatically when the cutters have bored to the required depth. The spindles of machines designed for working continuously on cylinders of a given size and cast solid, or *en bloc*, are not adjustable but have fixed center-to-center distances, as adjustment is not necessary. A special machine of this kind is only used in shops where large numbers of cylinders of one design are required continually. Some cylinder boring machines of the vertical type have spindles which can be adjusted for different center-to-center distances when this is necessary.

CYLINDER GRINDER. The planetary or eccentric-head type of grinder, which is now in common use, is so arranged that the cylinder casting does not revolve while being ground. The grinding wheel, as it revolves

rapidly about its own axis, is given a relatively slow circular or planetary motion, so that it is carried around the wall of the cylinder. At the same time, the cylinder, which is mounted on a carriage or slide of the machine, is given a lengthwise feeding movement which, for each complete circular movement of the wheel around the cylinder wall, is somewhat less than the width of the grinding wheel. The spindle-head of the grinding machine is so arranged that the eccentricity of the wheel-spindle or the diameter of the circular path it follows can be varied for grinding different diameters.

CYLINDER HONES. See Hones for Cylinders.

CYLINDERS, AUTOMOTIVE. According to the S.A.E. standard automobile nomenclature, an L-head cylinder has the valves on one side of the cylinder, a T-head cylinder has the valves on opposite sides, and an I-head cylinder has valves in the cylinder head. The term "cast in block" is used instead of " cast en bloc."

CYLINDER STRENGTH FORMULA. See Barlow's Formula.

CYLINDRICAL GRINDING MACHINES. The cylindrical grinder was first made in the early sixties as a grinding lathe by the Brown & Sharpe Mfg. Co., for the grinding of sewing machine parts. The regular manufacture of " grinding lathes " began in 1864, parts of 14-inch Putnam lathes being modified to permit mounting a grinding wheel on the carriage as well as an automatic feeding and reversing attachment and a dead center pulley.

Machines of the cylindrical type are intended primarily for grinding cylindrical parts, although they can also be used for taper work and other grinding operations, the extent of which may be increased considerably by the use of auxiliary equipment. For ordinary cylindrical grinding, the work is held between the centers of the machine, and it is rotated at a comparatively slow speed, while the grinding is done by a rapidly revolving grinding wheel. The machine is usually arranged so that the work is given a lateral feeding movement, in order that the wheel may cover the entire surface to be ground; some machines, however, are so constructed that the work rotates in one position and the wheel is given a traversing movement. Cylindrical grinding machines are equipped with a mechanism which enables the grinding wheel to be fed in automatically toward the work for taking successive cuts.

Cylindrical grinding machines, like milling machines, are divided into two general classes, known as *plain* and *universal* types. The wheel slide of a universal machine can be swiveled with relation to the travel of the table; the headstock can also be set at an angle, and provision is made for revolving the headstock spindle for grinding parts that are held in a chuck or otherwise. With a plain machine, the wheel slide is permanently set at right angles to the table travel and the headstock cannot be swiveled.

DADO JOINT. This type of joint is used in patternmaking and in other branches of woodworking, for securing the ends of ribs or partitions to the sides of boxes or frames. The rabbet-dado joint is a modified form for corners, which resists both inward and outward pressure. See Joints Used in Patternmaking.

DALTON'S LAW. A chemical law, known as Dalton's law, states that when two chemical elements form more than one compound with each other, the weights of the one which unite with a fixed weight of another bear a simple ratio to each other. For example, carbon unites with oxygen in two proportions, as carbon monoxide and as carbon dioxide. The latter compound contains the same amount of carbon, but exactly twice as much oxygen as the former. Nitrogen combines with oxygen in five compounds containing respectively two, three, four, and five times as much oxygen as does the first compound, the amount of nitrogen remaining the same. This law is also known as the "Law of Multiple Proportions."

DAMASCUS STEEL. A characteristic feature of damascene or Damascus steel is its surface patterns which vary with the carbon content and are either in the form of wavy parallel stripes or mottled patterns. This steel represents an early development in steel making, as it was imported during the Middle Ages to Western Europe through Syria and Palestine, and is known also as Indian steel and bulat. The old Indian method of producing real damascene steel consists in using a pure ore and the best grade of charcoal. The Persian practice is to use soft iron bars and charcoal and plumbago to supply the carbon; and a third method consists of a certain heat-treatment which resembles a prolonged tempering. One investigator has concluded that the carbon irregularly dispersed in the metal and forming two distinct combinations, is what causes the damask or characteristic pattern and that the slower the cooling the larger the veins will be.

The general but erroneous opinion is that the variegated surface of Oriental swords resulted from their being composed of a compound of bars and wires of iron and steel, welded and wrought together and then twisted by forging in different directions. A dagger blade of good damascene steel, properly hardened, cannot be broken by bending, but can be bent to such an extent that it loses its elasticity. When bent in the usual fashion, the blade flies back and retains its original shape. When bent more forcibly, the blade may not spring back again, but does not lose its original elasticity after straightening again. An imitation of Damascus steel can be obtained by etching the surface of the steel blade with acids, the parts which are not to be attacked by the acid being protected by a "resist."

DAMPING. The pointer of an indicating instrument of the type having a hand and graduated scale should preferably come quickly to its correct position on the scale, without oscillating to and fro. This enables readings to be taken with rapidity, and insures that the indications of the instrument follow correctly the fluctuations in the quantity being measured. To overcome the swinging of the moving parts first to one side and then to the other, of the point of rest, it is customary in the construction of electrical measuring instruments, to provide some form of "damping." The retarding force so utilized is produced by the motion of the parts, being zero when there is no motion, but increasing rapidly as the speed of the parts increases. Thus there is no hindrance to the moving element taking its correct position of equality between actuating and counter forces, but violent motions or oscillations are effectively retarded, and the instrument is said to be "dead beat" or "aperiodic."

Three forms of damping are in common use: 1. Air friction. 2. Electrical eddy-currents. 3. Liquid friction. Forms (1) and (3) are similar, in that both employ vanes or surfaces the motions of which are retarded according to the laws of fluid friction. *Air damping*, using light vanes or pistons swinging with small clearances in their enclosing boxes, is widely used for all classes of instruments. *Liquid damping* has more limited application; it is used in certain stationary instruments, and particularly where the parts are heavy and the forces great. In *eddy-current damping*, a conductor which is part of the moving system is arranged to move in the field of a magnet. The action of the resulting eddy-currents in the conductor upon the magnet provides the retarding or damping force. This form of damping is universally used in moving-coil permanent magnet instruments, where the conductor is readily supplied by winding the moving coil on a metal form, the magnet being already present. It is extensively used upon other types of instruments in the form of a metal sector swinging between the poles of a permanent magnet. Its most extensive application is in watt-hour meters, where a disk rotates in the air-gap between the poles of one or more permanent magnets. In this case, however, the damping force is utilized as the counter-force or control, since it fulfills the requirement of being directly proportional in amount to the speed of rotation.

DANIELL CELL. The Daniell cell is one of the well-known forms of wet electric batteries. It has a zinc anode and copper cathode with zinc sulphate for the electrode, although sometimes dilute sulphuric acid is used, and copper sulphate for the depolarizer. In its original form, it consists of a glass jar in which is placed the zinc cylinder, and within this a porous cup containing the copper-sulphate solution and the copper cathode. The rest of the jar is filled with zinc-sulphate solution. The E.M.F. de-

pends upon the density of the copper-sulphate solution and on the amount of zinc sulphate present in the dilute sulphuric acid. It is usually only from 1.07 to 1.14 volt.

DARBY PROCESS. A method for recarburizing the charge in a Bessemer converter. In this process the carbon is added by throwing anthracite or coke into the casting ladle as the steel is poured into it. The coke or anthracite is placed in large paper bags which have been carefully weighed so that each bag will give from 0.01 to 0.02 per cent of carbon to the steel.

DARCY'S FORMULA. Darcy's formula for the flow of steam in pipes gives the cubic feet of steam per minute which will flow through a pipe when the initial pressure, the terminal pressure, the diameter of the pipe, the weight per cubic foot of the steam at the initial pressure, and the length of the pipe, are known. The formula is of the following form:

$$Q = c\sqrt{\frac{(P - p)\,d^5}{wL}},$$

in which: Q = cubic feet of steam passing through pipe per minute; c = constant found from the accompanying table; P = initial pressure, in pounds per square inch; p = terminal pressure, in pounds per square inch; d = diameter of pipe, in inches; w = weight per cubic foot of steam at the initial pressure P; and L = length of pipe, in feet.

The table which gives the value of the constant c, also contains the fifth power of d, as used in the formula, for certain diameters of pipe.

Table of Constants and Fifth Powers

Diameter of Pipe, Inches	Value of Constant c	Fifth Power of d	Diameter of Pipe, Inches	Value of Constant c	Fifth Power of d
1	45.3	1	5	58.4	3,125
$1\frac{1}{2}$	48.5	6	6	59.5	7,776
2	52.7	32	7	60.1	16,807
$2\frac{1}{2}$	54.3	97	8	60.7	32,768
3	56.1	243	9	61.2	59,049
$3\frac{1}{2}$	57.1	523	10	61.8	100,000
4	57.8	1024	......	......	......

DE-ACCELERATION. De-acceleration or deceleration is the rate of change in the velocity of a moving body when the velocity is decreasing; or, specifically, the decrease in velocity of a body during a very short interval of time, usually one second.

DEAD BEAT. When the pointer or indicating hand of an electrical or other measuring instrument, moves to position without violent and

prolonged oscillations, the instrument is said to be "dead beat" or aperiodic. The excessive oscillations are prevented by some method of damping. See Damping.

DEAD CENTER. This term as applied to machine tools relates to the stationary center on which work revolves while being machined. In a lathe, the dead center is that mounted in the tailstock. In grinding machines, both centers frequently are stationary or dead.

An engine is said to be on the "dead center" when the piston is at one end of the stroke, the crank, connecting-rod, and piston-rod being in a straight line. The name "dead center" is derived from the fact that, when the crank and piston are at the end of the stroke, the steam pressure does not exert a turning force upon the crank, the thrust of the piston being transmitted directly to the shaft and bearings.

DECALESCENCE POINT. The decalescence point is the temperature at which a decided change in the internal condition of steel takes place, and above which steel must be heated in order that it may be properly hardened by quenching. Generally speaking, the decalescence point of any carbon steel marks the correct quenching temperature of that particular steel. When steel is heated, it reaches a point where it will absorb heat for a brief period without a rise in the degree of temperature of the steel; this point is the decalescence point. As soon as this point has been reached, the steel is ready to be removed from the source of heat; the quenching then checks or traps the steel in the condition into which it has been changed at this temperature. The decalescence point is not the same for all steels, but occurs for most carbon steels at temperatures between 1350 and 1450 degrees F.

DECKING. In a belt conveyor installation, the protection provided for preventing the material being transported from falling onto the reverse side of the lower returning belt is called "decking." If gritty material falls on the reverse side of the belt it will become imbedded as the belt passes over the pulleys, and will gradually wear and destroy the belt.

DECOMPOSITION. In chemistry, a chemical reaction in which a compound is divided into two or more products.

DEDENDUM. A committee of the American Gear Manufacturers' Association has given the following definition: "Dedendum is the distance, normal to the pitch surface, from the pitch surface to the bottom of the tooth space." Therefore the dedendum of a gear tooth is the distance from the pitch circle to the root of the tooth. In the involute system of cut gearing, the *dedendum* is equal to the *addendum* plus the clearance. As the addendum is equal to 1 divided by the diametral pitch, and the clearance is equal to 0.157 divided by the diametral pitch, the dedendum,

or depth of the tooth below the pitch-line, is always equal to 1.157 ÷ diametral pitch.

In cast gearing, when the tooth dimensions are based upon the circular pitch, the dedendum is frequently made equal to 0.4 times the circular pitch. In the Nuttall Co.'s system of stub gear teeth, the dedendum is equal to 0.3 times the circular pitch. In bevel gearing, the dedendum is the depth of the tooth space below the pitch-line at the large end of the tooth.

DEFLOCCULATED GRAPHITE. Deflocculated graphite is a lubricant consisting of finely divided graphite suspended in water or oil, by means of a small quantity of gallotannic acid, which, when added to the water, prevents the graphite from settling to the bottom. The graphite seems to entirely dissolve in the water, under these conditions. The black liquid will easily pass through the finest filter paper. Severe tests have demonstrated that it is a satisfactory lubricant. Deflocculated graphite also possesses the remarkable power of preventing rust or corrosion of iron or steel. The graphite appears to entirely neutralize the effect of the water in which it is suspended. Light and thin oils, when used in conjunction with deflocculated graphite, can be used in place of the heavy and expensive lubricating oils. The lasting qualities of these graphite lubricants are greater than the oil lubricants which they often displace.

DEGREE. The degree is the unit of angular measurements and is equal to $\frac{1}{360}$ of the circumference of a circle. One degree is subdivided into 60 minutes, and 1 minute, into 60 seconds. The degree is also the unit of measurement for temperature, thermometers being graduated in degrees. The value of 1 degree of temperature varies on the different thermometer scales. Electrical degrees are referred to in connection with alternating electric currents. One complete cycle — that is one complete set of positive and negative values of an alternating current — is equal to 360 electrical degrees; hence, an electrical degree is $\frac{1}{360}$ of a cycle.

DELTA CONNECTIONS. In a three-phase alternating-current system, the generators and motors are designed with three windings or phases which are either connected in mesh or delta connection, so called because the diagram of the three windings forms a Greek letter "delta" (Δ), or connected in star, which is then called a Y-connection, because the diagram of the three windings forms a "Y."

DELTA METAL. Delta metal is an alloy consisting mainly of copper and zinc with small percentages of iron and tin. The percentages of its composition vary somewhat, but it is composed generally of about 60 per cent of copper, 36 per cent of zinc, 2 per cent of iron, and 2 per cent of tin.

DEMAGNETIZER. Hardened tool-steel parts that have been held on a magnetic chuck become permanently magnetized, and this is also true,

in a slight degree, of cast-iron parts. This residual magnetism is objectionable for some classes of work, and a device known as a " demagnetizer " is used for removing it. This apparatus consists of an iron base upon which is mounted a wooden box containing a revolving member in the form of a magnet held in a rotating framework; a pulley for rotating the demagnetizer is provided. The cover of this apparatus is detachable and supports a mass of laminated sheet-iron plates which are in contact with two metal plates attached to the top cover. After the apparatus is set in motion, all traces of magnetism may be removed from the work by simply moving it several times in and out of contact with these metal plates. The phenomenon of demagnetizing may be briefly explained as follows: The iron plates at the top of the apparatus represent the poles of a magnet in which the polarity is rapidly reversing. This reversal of polarity is transmitted to the work in contact with the plates. At the moment of reversal, however, there is a neutral point in which, for an instant, there is no magnetism. In removing the work out of a strong magnetic field to a weaker one (by lifting it away from the apparatus), it has moved a certain distance during the time that the magnet is neutral, and, when next charged, being in a weaker field, it does not take as strong a charge as before; thus, by a repetition of this movement, the magnetism is finally removed entirely.

DENSITY. The density of any solid, fluid, or gaseous substance is the mass of that substance per unit volume. If weight is used in the ordinary sense as being equivalent to mass, then the density may be defined as the weight per unit volume. It is then evident that the numerical value of the density of a substance depends upon the unit in which the mass or weight is expressed, and also upon the unit of volume used. In engineering and scientific work, however, the density of a substance is generally expressed in grams per cubic centimeter, without naming the units, because, when so expressed, the density will, for all practical purposes, be equal to the specific gravity.

DEOXIDIZED BRONZE. An alloy containing copper and tin as its chief constituents, generally being composed as follows: Copper, 82.5 per cent; tin, 12 per cent; zinc, 3.4 per cent; lead, 2 per cent; and iron, 0.1 per cent.

DEPOLARIZER. Hydrogen is a non-conductor, so that a layer of it on the cathode would prevent the passage of the current; a cell in that condition is said to be *polarized*. Any substance that, when placed in the electrolyte or on the electrodes, will partly or entirely prevent this collection of hydrogen on the cathode is called a *depolarizer*. Polarization decreases the electromotive force of the cell. If the depolarization is obtained

by purely mechanical means, the internal resistance is increased. If the liberated hydrogen is caused to recombine at the cathode by chemical means, the internal resistance is not increased, but the electromotive force may be augmented.

DEPRECIATION. Depreciation is the decrease in value of machinery, tools, appliances, and buildings due to deterioration, loss of usefulness, and other causes. The percentage of annual depreciation depends largely upon the estimated length of life of the machines and appliances. These estimates vary widely. As regards the depreciation of machinery, the amounts to be deducted annually from the initial cost are approximately as follows: Lathes and machine tools, first class, 5 per cent; engines, shafting, gearing, and mill-work, $7\frac{1}{2}$ per cent; lathes and machine tools, second class, 10 per cent; machinery in general, 10 per cent; boilers, $12\frac{1}{2}$ per cent; leather belting, 40 per cent.

DESIGN PATENT. In the language of patent law, the word "design" does not mean the physical arrangement of the parts of a machine, but refers solely to its ornamental appearance. A design patent gives its inventor a monopoly to the exterior appearance of the thing patented.

A design patent may be obtained by any person who has invented any new, original, and ornamental design for any article intended to be manufactured, but the interior views, or other parts that will not be seen when the apparatus actually is performing its service, cannot be protected. A simple legal form, together with the required drawing, comprises a complete application for a design patent. See Patent on Design.

DESSIATINE. A Russian square measure, equal to 2.7 acres.

DETINNING. The recovering of tin from tin scrap, old tin cans, etc., is known as *detinning*. Two methods are in use for this purpose. One method is based upon purely chemical means, the tin being converted into tin tetrachloride by treating it with dry chlorine. The other method is electrolytic, the tin being dissolved and deposited in the metallic state.

DIAGRAMS. Diagrams are used for obtaining unknown factors in a problem without carrying out the calculations required in figures; they may also be used for checking the results of calculations made by figures. The results are obtained by simply following the lines in the diagram in a certain manner, which may be different for different diagrams. Each diagram covers a large number of problems of the same type, but for different kinds of problems other diagrams must be devised.

Practically all engineering information that can be presented in tabular form can be arranged also in the form of a diagram. There is, however, a very distinct difference between the kind of information that can best be

recorded in diagrams and in tabular form. When there are only a comparatively few dimensions or sizes, varying by definite intervals, a table is better than a diagram; for example, if it is desired to list dimensions of machine details that are made in a specified number of sizes, a table giving the necessary dimensions has every advantage over a diagram. On the other hand, when there is a large number of combinations of different factors, the diagram performs a service that a table cannot, unless it is made so large and elaborate as to be impracticable. For example, a diagram relating to the horsepower transmitted by gears of different pitches, widths of face, numbers of teeth, and running at different speeds, is entirely practicable; whereas a table giving all such possible combinations would be too voluminous.

Whenever all the facts can be simply and easily recorded in a table, that method is generally best. If the variables are so many that a table becomes too voluminous, then the diagram will best fill the requirements.

Often diagrams are useful for visualizing a trend or tendency, because a curve will show this much more clearly than a set of figures. This, however, is a use for the diagram distinctly separate from that contemplated in the foregoing, where tables and diagrams are used merely as convenient methods for recording information, and for obtaining unknown dimensions and sizes that depend upon, or correspond to, some known dimension.

DIAGRAMS, VALVE. See Valve Diagrams.

DIAL FEEDING MECHANISMS. Automatic feeding mechanisms of the dial type are used in conjunction with power presses for parts which have been partly finished by previous operations. The parts to be operated upon are placed in the pockets of the dial feeding mechanism, and as the punch descends the dial revolves automatically, stopping just before the punch enters a pocket. After the operation is performed, the part is automatically ejected from the dial, leaving the pocket empty for another cup or blank. There are two different types of dial feeds in general use. The *friction-dial feed* consists of a plain disk which revolves continuously in combination with stationary guides and gages above it, so that the pieces placed on the disk are fed accurately under the punch. In order to insure reliable action, there is usually a finger or gripping movement which places and holds the work in the correct position. The friction-dial feed is preferable for redrawing short shells or pieces which are not liable to topple over. The other type is known as the *ratchet-dial feed* and consists of a circular plate which connects with the main shaft through a medium of cams and pawls so as to receive an intermittent rotary motion. This disk has a number of holes or pockets to receive either the work or dies. By means of this feed, it is possible, in many cases, to subject the pieces to

two or three consecutive operations without rehandling. Feed mechanisms of the dial type are commonly used for carrying blanks, shells, or cup-shaped parts under the punch to receive a second and third operation. They are extensively employed in connection with the manufacture of brass goods, trimming, buttons, cartridge and primer shells, and tubes for pen and pencil cases, and many other specialties.

DIAL GAGE. The dial gage is a form of gage having a graduated dial and a hand which is connected to a test-point by a system of multiplying levers, so that a very slight movement of the test-point is greatly magnified by the indicating hand. This test-point is placed in contact with the part to be tested, and variations, either in size, alignment, or concentricity, depending upon how the gage is used, are shown by the movements of the hand relative to the dial, which is graduated to read to thousandths of an inch. Dial gages are used in combination with many different forms of gaging devices.

DIAMAGNETISM. Materials, like iron and steel, that are attracted by the poles of a magnet, are known as " magnetic "; those that are not attracted by a magnet are generally known as " non-magnetic." It has been shown, however, that practically all substances are acted upon in some manner by a sufficiently strong magnetic pole, but only a comparatively small number are attracted like iron, while the great majority of materials are repelled. Those substances that are repelled by the magnetic pole have been termed " diamagnetic." The strongest of all diamagnetic metals is bismuth; that is, of all substances this metal is repelled by a magnetic pole more than any other. Its diamagnetic qualities are so pronounced, in fact, that they can be detected by means of any good permanent magnet. Of the metals, gold, silver, copper, lead, zinc, antimony, mercury, and bismuth are all diamagnetic, while tin, aluminum, and platinum are attracted by a very strong magnetic pole.

DIAMETRAL PITCH. The common method of designating the size of the teeth of cut gearing is by giving the *diametral pitch*, which is a number representing the number of gear teeth per inch of pitch diameter. For example, a gear of 6 diametral pitch has 6 teeth around its circumference for each inch of pitch diameter; therefore, if a gear of 6 pitch has 60 teeth, the pitch diameter must equal $60 \div 6 = 10$ inches. The *circular pitch*, which is sometimes used for designating the sizes of very large gear teeth and especially for cast gears, is equal to the dimension from the center of one tooth to the center of the next one measured along the pitch circle. If 3.1416 is divided by the circular pitch, the equivalent diametral pitch will be found, and inversely, if 3.1416 is divided by the diametral pitch, the result will equal the circular pitch.

The diametral pitch system is so arranged as to provide a series of tooth sizes, just as the pitches of screw threads are standardized. Inasmuch as there must be a whole number of teeth in each gear, it is apparent that gears of a given pitch vary in diameter according to the number of teeth. Suppose, for example, that a series of gears are of 4 diametral pitch. Then the pitch diameter of a gear having, say, 20 teeth will be 5 inches; 21 teeth, $5\frac{1}{4}$ inches; 22 teeth, $5\frac{1}{2}$ inches, and so on. It will be seen that the increase in diameter for each additional tooth is equal to $\frac{1}{4}$ inch for 4 diametral pitch. Similarly for 2 diametral pitch the variations for successive numbers of teeth would equal $\frac{1}{2}$ inch, and for 10 diametral pitch the variations would equal $\frac{1}{10}$ inch, etc.

The center-to-center distance between two gears is equal to one half the total number of teeth in the gears divided by the diametral pitch. While it may be desirable at times to have a center distance which cannot be obtained exactly by any combination of gearing of given diametral pitch, this is an unusual condition and ordinarily the designer of a machine can alter the center distance whatever slight amount may be required for gearing of the desired ratio and pitch. By using a standard system of pitches all calculations are simplified, and it is also possible to obtain the benefits of standardization in the manufacturing of gears and gear-cutters. The range of diametral pitches ordinarily used is 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$, 2, $2\frac{1}{4}$, $2\frac{1}{2}$, $2\frac{3}{4}$, 3, $3\frac{1}{2}$, 4, 5, 6, 7, 8, 9, 10, 12, 14, 16, 18, and 20. For very small gears, finer pitches of even number diametral pitches are employed. The diametral pitch system, which was long known as the "Manchester pitch," was originated by a Swiss named John George Bodmer, in his plant at Manchester, England.

DIAMOND. A form of the chemical element carbon which is extremely hard. In its pure form, it is exceedingly clear and transparent, but numerous impure varieties, known as "black diamond" and "bort," are dark in color. These latter are used in the industries for dressing grinding wheels, and in some cases for cutting tools. The specific gravity of carbon in the form of diamond is about 3.5.

DIAMOND ALLOY. Diamond alloy is a non-ferrous alloy composed mainly of chromium, molybdenum, and tungsten combined in proportions and by processes that result in a metal so hard that cutting tools made from it possess an unusual resistance against wear. Another favorable property is that tools made from the alloy may be used under conditions of feed and speed that raise the temperature almost to the fusion point without there being any tendency of the cutting edge to soften. The metal is non-magnetic, a property that is desirable under certain conditions. The alloy cannot be forged, but milling cutters, slitting saws, reamers and other tools of this general character are cast in permanent molds.

DIAMOND CHISEL. A chisel with a narrow blade having the cutting edge at one corner of a square-shaped end. It is intended for cutting V-grooves having a sharp bottom.

DIAMOND DUST. Diamond dust is commonly used for lapping or grinding small precision work in tool-rooms, watch factories, etc., where great accuracy is required. The grades of diamond dust used for charging laps are designated by numbers, the fineness of the dust increasing as the numbers increase. The diamond, after being crushed to powder in a mortar, is thoroughly mixed with high-grade olive oil. This mixture is allowed to stand 5 minutes and then the oil is poured into another receptacle. The coarse sediment which is left is removed and labeled No. 0, according to one system. The oil poured from No. 0 is again stirred and allowed to stand 10 minutes, after which it is poured into another receptacle and the sediment remaining is labeled No. 1. This operation is repeated until practically all of the dust has been recovered from the oil, the time that the oil is allowed to stand being increased finally to several hours, in order to obtain the smaller particles that require a longer time for precipitation.

DIAMOND LAP. Very small holes in precision work are often finished after drilling, by using a rotary diamond-charged lap. Laps of this kind are made of mild steel, and the slightly enlarged working end is charged with diamond dust, thus converting it into an efficient grinding wheel for small holes. Such a lap may be charged by rolling it between hardened steel plates, after placing a little diamond dust and oil on the lower plate. The spindle is revolved by a round belt connecting with the grinding pulley on the countershaft. The spindle speeds for small grinding and lapping operations usually vary from 10,000 to 12,000 revolutions per minute.

DIAMONDS FOR WHEEL-TRUING. There are five different kinds of diamonds employed for truing grinding wheels, namely, Jaegers-Fontin, Ballas, black carbon, brown bort, and gray bort. The Jaegers-Fontin diamond is very hard and is the most brittle kind. It is grayish in color, irregular in shape, and possesses a very coarse grain. It fractures easily, usually at the wearing point, which chips off in little pieces. It may be set firmly without difficulty on account of its rough surface, but this surface makes it difficult to true wheels satisfactorily. In addition to these disadvantages, these diamonds are very expensive.

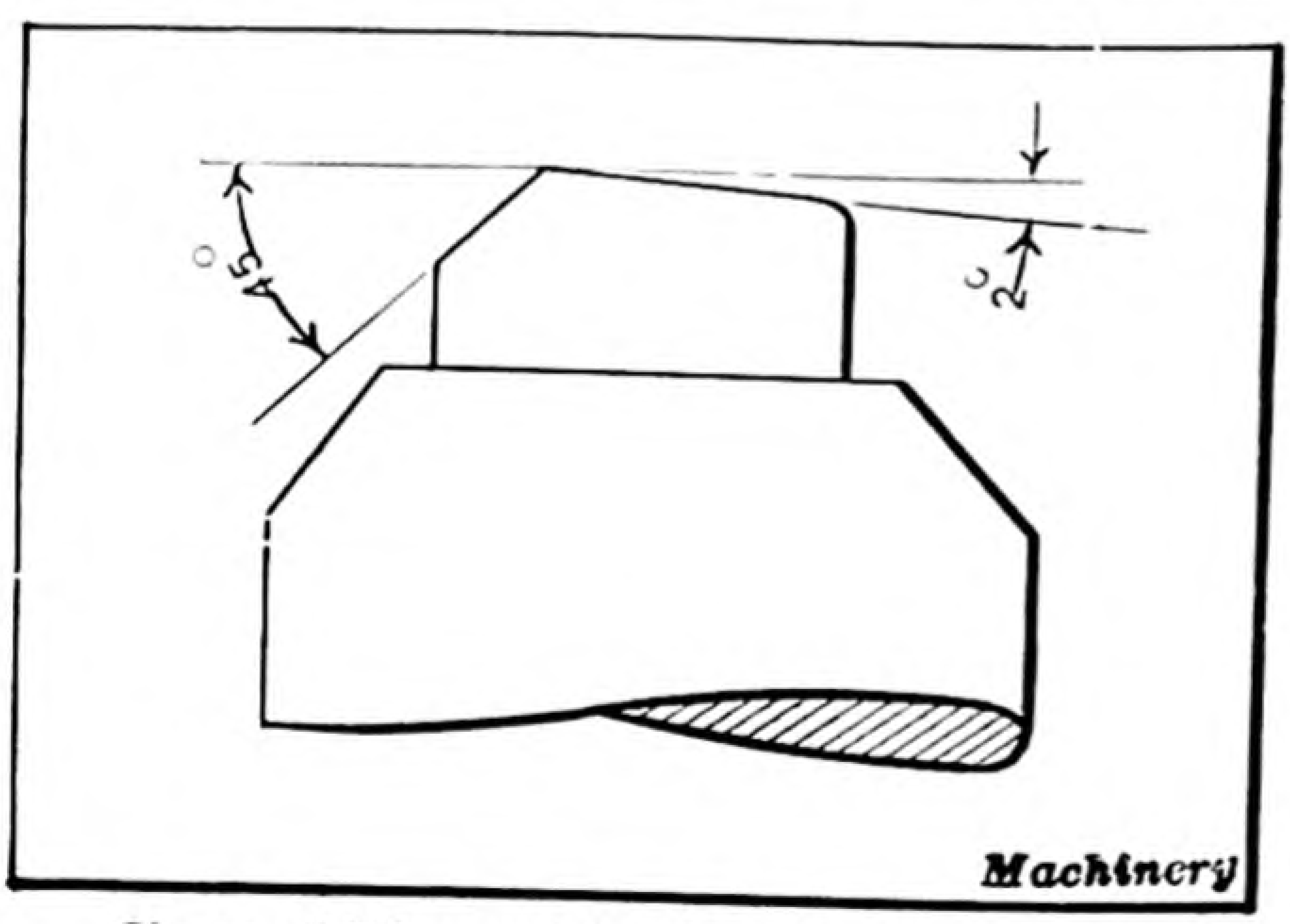
The Ballas type of diamond is a clear white stone, hard and brittle, but not to the same degree as the Jaegers-Fontin type. It is of a finer grain than the latter and generally gives more satisfactory results. The black diamond is soft but tough. It does not break but wears too quickly to be suitable for the purpose of truing grinding wheels. It is also very expensive. Of the bort types, the brown stone has a smooth surface and a fine

grain, and is transparent. It is not as hard, however, as either the Jaegers-Fontin or the Ballas types, but it is very tough. The color of the stone is produced by the presence of iron oxide. The gray stone is much the same as the brown stone except for the color and for the fact that it is a little harder and more brittle. The bort stones are sufficiently hard to withstand all reasonable wear, their shape is such as to permit them to be securely set and they are relatively inexpensive.

The shape of the wheel-truing diamond is an important factor in determining its value, the ideal shape being an eight-sided stone. The diameter and face of the grinding wheel, its hardness, and the type of abrasive used are factors which should be considered when determining the proper size of stone to use. A diamond should never be used on a grinding wheel which is mounted on a loose spindle, as the tendency will be to shatter the diamond and probably to pulverize it. The diamond should never be rammed into the grinding wheel, and should not be traversed across the face of the wheel too quickly. It is important that a stream of water be used during the truing-up operation.

DIAMOND SUBSTITUTE. A material which is intended to replace diamonds in stone-cutting and core-drilling is known as phoran. See Phoran.

DIAMOND TOOLS FOR METAL CUTTING. Tools with diamond cutting points are used to a limited extent for certain metal-cutting operations on precision work, especially when a tool of extreme durability is required to obtain the necessary accuracy. Diamond tools have been used chiefly for machining non-ferrous metals, such as brass, bronze, aluminum and German silver. They have also been used for machining steel and cast iron to a very limited extent, but there is a difference of opinion as to their practicability for ferrous metals. Various non-metallic materials may be cut readily with diamond tools, as, for example, hard rubber, fiber, strawboard, gutta-percha, and bakelite.



Shape of Diamond for Turning Operations

Diamond tools are especially adapted to fine instrument and tool work and they are used in some automobile plants for finishing connecting-rod and line bearings. Work having a uniform diameter over a considerable

length, such as the brass sliding tubes of a telescope or hard rubber typewriter rolls, may be turned without perceptible diameter variations occurring in thousands of parts. In fact, diamond tools may be used almost indefinitely without regrinding as indicated by the fact that tools turning brass tubing in one shop were used continuously for eighteen months without regrinding. Diamond tools are used extensively for the various turning and boring operations on the hard rubber parts of fountain pens, it being possible to produce hundreds of thousands of these parts without resetting the stone. In one plant, brass castings up to 12 inches in diameter and 3 feet in length have been finished to size within 0.0002 inch throughout the entire length, while taking cuts $\frac{1}{16}$ inch deep; furthermore, these cuts were through the outer scale of the castings.

Kinds of Diamonds Used. — Brown Brazilian or African diamonds which are off color and unsuitable for jewelry are used for metal cutting. Black or "carbon" diamonds used in dressing grinding wheels have been used, and while satisfactory results were obtained in cutting rubber, bakelite, etc., these diamonds were found unsuited for the precision cutting of metals. It is essential that the diamonds used for this purpose be of close grain and free from carbon spots, so that a keen cutting edge may be ground. The largest diamonds used for industrial purposes are about 20 carats, and the smallest size used in a cutting tool, $\frac{1}{8}$ carat. It is advisable to use a diamond of the largest possible size that is suitable for the work at hand, as this permits the diamond to be reset if necessary; also a large diamond has a greater percentage of salvage value than a small diamond, thus making the net cost much less.

Method of Holding Diamonds. — Diamonds of the kind used are of a laminated structure, the boundary of each layer being known as a "cleavage plane." Each diamond is studied carefully to determine the location of the cleavage planes, and then split "along the grain." When placed in the holder, a diamond must be set properly in relation to the cleavage planes, because later, in grinding the diamond to obtain a cutting edge, it is ground along the selected cleavage plane the same as a wooden board is planed along the grain. The diamonds used in one plant are set into $\frac{3}{8}$-inch round steel holders. These holders are usually mounted in a flat bar which has a hole bored into the front end to receive the holder.

Preparatory to setting a diamond, a hole of about the diameter of the diamond is drilled in one end of the holder and eight fine slots are cut radially from this hole with a hacksaw. The diamond is then inserted in the hole, and the slotted sections of metal are squeezed and clamped securely against the diamond to hold it in place while it is brazed in the holder. The excess brass and part of the metal at the end of the holder in which the diamond is inserted, are then ground away.

Shape of Diamond Tool. — Diamonds can be ground for outside turning, boring, radius turning, facing, and, in fact, for almost any lathe operation for which high-speed steel tools are suited. Pointed tools are ground to various included angles between 60 and 120 degrees. Turning tools are usually ground to a 45-degree angle at the left-hand end of the cutting edge (see illustration), the width of the bevel depending upon the depth of cut to be taken with the tool. The wide front portion of the cutting edge is ground at an angle of 2 degrees from the bevel, and a clearance of 2 degrees is ground on the front face of the diamond when the tool is to be used for cutting brass and aluminum. For cutting cast iron, this clearance angle amounts to 5 degrees. All types of tools, whether intended for turning, boring, facing, etc., are given the same amount of clearance. The top surface of all diamonds is ground flat.

Cutting Speeds. For diamond tools, cutting speeds of about 200 feet per minute are recommended. In one shop, a speed of 180 feet per minute is used while boring bronze bushings. In another plant where diamonds are used extensively on small instrument work, the lathes have speeds varying from 1500 to 2000 revolutions per minute, and roughing cuts are from 0.016 to 0.022 inch and finishing cuts, from 0.006 to 0.012 inch. It is essential to avoid tool chatter or work vibrations when using diamond tools.

DIAMOND WIRE-DRAWING DIES. Dies made from diamonds are used extensively for drawing small sizes of wire. Such dies are now employed almost exclusively for wire ranging from 0.080 inch down to 0.0004 inch in diameter; and owing to their durability and other advantageous features, diamond dies are now finding quite a wide application for drawing larger sizes of wire. When they are properly made, the use of these dies is economical. Although their first cost is high, diamond dies retain their accuracy for a long time and they can be repeatedly recut, so that the item of die cost which must be charged against the expense of manufacturing wire, is distributed over a very large quantity of the product. For this reason, diamond dies have largely replaced the use of dies made from steel, iron, ruby, or sapphire. Most diamond dies are made of rough diamonds from the South African and Australian mines, the diamonds used for this purpose being of a grade which is unsuitable for use in jewelry. Diamonds from the mines are shipped chiefly to London, and from that market they are exported to different cities in France where the majority of the dies used in wire-drawing are made.

These dies consist of a body made from brass or bronze through which is drilled a clearance hole for the wire, which hole is counterbored to a certain depth. The counterbored hole constitutes a seat for the diamond which is set in the center of the hole with molten brass or solder poured in around it until the hole is filled. The diamond is perforated by a tapering

polished hole through which the wire is drawn. In many wire-drawing mills, the sizes for which diamond dies are used are limited to from 0.002 to 0.040 inch. The size of diamond for a wire 0.040 inch in diameter is about 3 or $3\frac{1}{2}$ carats, while $\frac{1}{2}$-carat stones will suffice for dies for drawing wire 0.010 inch in diameter.

DIBASIC ACID. In chemistry, an acid which has two atoms of hydrogen in each molecule replaceable by a metal.

DIE. The term "die" is often applied to an entire press tool including both upper and lower members, while the names "punch" and "die" are used to designate parts or sections of a complete die. These main sections ordinarily are classified with reference to shape, rather than by location, notwithstanding the fact that the punch is usually but not invariably the upper member. When the name "die" is applied to part of a press tool, it refers to the member that has an opening or cavity to receive a punch, for blanking, drawing, or otherwise forming whatever stock or part is confined between the punch and die members. See also Punch.

DIE-BLOCK. A block in which the die is held in a punch press. The die-block itself is bolted to the bed of the press. It is also known as Bolster.

DIE-CASTING. The term "die-casting" generally refers to a casting that has been made in a metallic mold or die, into which molten metal has been forced under the influence of either mechanical or pneumatic pressure. Die-castings do not include so-called "hot-pressed" or "die-pressed" forgings, because in this process, the metal placed in the dies is not molten, but merely in a plastic or semi-plastic condition. The definition also excludes castings that are poured by gravity into metallic molds, the latter generally being known as "permanent-mold" castings. Die-castings may be defined as castings produced by forcing molten metal into metallic dies by a force greater than atmospheric pressure. This definition differentiates them from the class of castings made by the permanent mold process, sometimes referred to as die-castings. Die-castings are uniform, accurate, and cheap, equal to the product of a skilled workman, but produced by unskilled labor. Their advantage over machined parts is due to the rapidity with which they are produced and the relatively small amount of labor necessary after they are cast to produce a finished piece ready to be assembled.

The process of die-casting requires the use of a die-casting machine, and consists essentially in melting the die-casting alloy in a suitable container and forcing it, under pressure, into metallic molds or dies, allowing it to cool in them, and then opening the dies and removing the casting, thereby producing smooth finished castings requiring little or no machining

and being ready for buffing or plating without any grinding or other abrasive process. The method is best adapted to small intricate parts where accuracy and uniformity are essential. The history of type founding shows that in 1838 the first casting machine for type, invented by Bruce, was a machine that involved the principles of die casting as it is now practiced. More recently, in 1885, Otto Mergenthàler brought out the linotype machine. This machine is a good example of a die-casting machine. However, as understood to-day, *die casting* is a broader term than *type casting*, although its development is, without doubt, due, in part, to the success of the linotype machine.

The properties of die-castings will depend upon the nature of the alloy used. The die-casting process is best adapted to alloys of comparatively low fusing points which, for convenience, may be divided into the following groups:

1. Zinc alloys, consisting essentially of zinc alloyed with tin, copper, or aluminum.
2. Tin alloys, consisting essentially of tin alloyed with copper, lead, or antimony.
3. Lead alloys, consisting essentially of lead alloyed with tin or antimony.
4. Aluminum alloys, consisting essentially of aluminum alloyed with copper.

DIE-CASTING ALLOY, ALUMINUM BASE. A typical aluminum alloy for die-casting is composed of 92 per cent aluminum and 8 per cent copper. The properties of this alloy are as follows:

Color	Silver white
Weight per cubic inch	0.115 pound
Melting point	1150 degrees F.
Tensile strength	21,000 pounds per square inch
Elongation	1.5 per cent
Hardness number (Brinell)	60.5

The maximum weight of castings made from aluminum alloys is about 5 pounds, with a minimum wall thickness of $\frac{1}{16}$ inch and a variation from the given dimensions of 0.0025 inch per inch of diameter or length. The finest thread that can be successfully cast is 20 threads per inch externally; internal threads are rarely cast. Frequently, the external threads are cast 0.010 inch over size and are finished to size by a cutting tool. The minimum diameter of cast holes is about $\frac{3}{32}$ inch and these holes cannot be made deeper than 1 inch. Larger holes may be cast much deeper, and smaller holes may be spotted to facilitate drilling. The draft of cores should be 0.015 inch per inch of diameter or length, and the draft of side

walls 0.005 inch. Cores less than $\frac{1}{4}$ inch in diameter do not need more than 0.005 inch draft per inch of length.

The aluminum alloy used for die-casting is well known in the trade as No. 12 alloy and it is used extensively for automobile and airplane parts. By varying the copper content, harder or softer alloys may be obtained, all of which may be die-cast successfully. Aluminum die-castings find wide employment in the manufacture of parts of automobiles, such as spark and throttle control sets, magneto parts, battery ignition and lighting systems, speedometers, etc. They are also used for parts of vacuum sweepers, phonographs, milking machines, vending machines, etc.

DIE-CASTING ALLOY, LEAD BASE. The following table gives the composition of typical alloys in the lead-alloy group which are used for die-castings:

	Lead, Per Cent	Tin, Per Cent	Antimony, Per Cent
1	83	0	17
2	90	0	10
3	80	10	10
4	80	5	15

Alloy No. 1 is generally known as C. T. (coffin trimming) metal, due to its extensive use in the manufacture of coffin trimmings. This alloy is also a good bearing metal for light duty, and is used for thrust washers and camshaft bearings on light internal-combustion engines. No. 2 is somewhat softer and more ductile than No. 1. No. 3 is used extensively for light bearing duty, being somewhat tougher and stronger than Nos. 1 and 2. No. 4 is somewhat harder than No. 3, but less ductile.

The maximum fusing point of alloys of this type is about 600 degrees F.; the maximum weight for castings made from lead alloys, 15 pounds; the minimum wall thickness, $\frac{1}{32}$ inch; the variation from the given dimensions per inch of diameter or length, 0.001 inch; the finest number of threads that can be cast externally, 24 per inch; the number of threads cast internally depends upon various conditions. The minimum diameter of cast holes is $\frac{1}{32}$ inch, depending, however, on the depth and general design of the casting. The draft for cores is 0.0005 inch per inch of length and diameter, and for side walls, 0.001 inch per inch of length.

Lead alloys may be used where a metal of non-corrosive properties is desired and where a tensile strength of not over 8000 pounds per square inch will suffice. They are used extensively for fire-extinguisher parts, low-pressure bearings, ornamental metalware, and many parts that come in contact with corrosive chemicals. They should not be used for parts that may come in contact with foods or that may be handled often in service, on account of the poisonous properties of lead and lead alloys.

The main advantage of these alloys lies in their comparatively low cost, but their high specific gravity must be considered, some lead alloys having a specific gravity double that of the zinc alloys.

DIE-CASTING ALLOY, TIN BASE. The following table gives five typical tin alloys generally used for die-castings:

	Tin, Per Cent	Copper, Per Cent	Lead, Per Cent	Antimony, Per Cent
1	90	4.5	0	5.5
2	86	6	0	8
3	84	7	0	9
4	80	0	10	10
5	61.5	3	25	10.5

Alloy No. 1 is a so-called "genuine babbitt" metal, and was used very extensively during the war for main-shaft and connecting-rod bearings on all American-made airplanes and motor trucks. No. 2 is somewhat harder, and is used extensively for bearings of internal-combustion engines. No. 3 is somewhat harder than alloy No. 2, and is the S.A.E. standard for high-grade internal-combustion-engine bearings. No. 4 is in general use for light bearings on stationary motors. No. 5 is a bearing metal for light duty, and is used on a large number of moderate-priced automobiles for main-shaft and connecting-rod bearings.

The maximum fusing point of tin alloys is about 450 degrees F.; the maximum weight for castings made from these alloys, about 10 pounds; the minimum wall thickness, $\frac{1}{32}$ inch; the variations from the given dimensions per inch of diameter or length, 0.0005 inch; and the finest pitch of thread that can be cast externally, 27 threads per inch, while the number of internal threads depends upon various conditions. The minimum diameter of hole that can be cast is $\frac{1}{32}$ inch, but this diameter depends on the depth of the hole and the type of the casting. The required draft for cores is 0.0005 inch per inch of length or diameter, and for side walls, 0.001 inch per inch of length.

Tin alloys find their largest field of application in their use as bearings for internal-combustion engines. They are also used for parts of soda fountains, cream separators, milking machines, surgical apparatus, galvanometer parts, player pianos, etc., where a tensile strength of over 8000 pounds per square inch is not essential and where resistance to corrosion is of importance. They are not affected by water, weak acid or alkaline solutions, and when free from lead, are extensively used for food-container parts.

DIE-CASTING ALLOY, ZINC BASE. A typical zinc alloy suitable for die-casting consists of 87.5 per cent zinc, 8 per cent tin, 4 per cent copper,

and 0.5 per cent aluminum. The properties of this alloy are as follows:

Color	Silver white
Weight per cubic inch	0.253 pound
Melting point	780 degrees F.
Initial fusing point	275 degrees F.
Tensile strength	16,100 pounds per square inch
Elongation	2 per cent
Compressive strength	27,670 pounds
Hardness number (Brinell)	64.6

The weight of the die-castings made from this alloy is generally not more than 8 pounds. The minimum wall thickness varies from 0.1 inch for larger castings to $\frac{1}{16}$ inch for smaller castings. The variations in dimensions per inch of diameter or length may be held to 0.001 inch. Twenty-four threads per inch is about the finest pitch that can be cast on external threads, while the number of threads per inch that can be cast on internal threads depends on the conditions in each case. The minimum diameter of cast holes is $\frac{1}{32}$ inch, but this depends largely upon the shape and thickness of the casting. The draft necessary for cores is 0.001 inch per inch of length or diameter, and for side walls 0.001 inch per inch of length. The sections of the castings should be as uniform as possible. Sharp corners should be avoided and fillets should be added wherever permissible. Undercuts in casting should be avoided wherever possible.

Alloys of this type are corroded by any alkaline or aqueous solution of salts. The castings may be polished to a high luster, but soon tarnish when exposed to ordinary atmospheric conditions. Castings made from this alloy may be readily plated with nickel, copper, brass, silver or gold. When they are properly plated, such castings will retain their luster as well as those that are made from either brass or bronze. These castings should not be used for parts that are subjected to severe stress or sudden shock in service. They are used extensively for parts of phonographs, calculating machines, drinking cups, vending machines, magneto housings, automobile-body trimmings, pencil-sharpening machines, time-recording devices, stamp-affixing machines, and for a great many other devices that are of a kindred nature.

DIE-CASTING MACHINE. Although many types of die-casting machines have been used in different stages of the development of the die-casting industry, those now in general commercial use are either of the plunger type or of the compressed air type. In the plunger type machine compressed air is admitted to a cylinder to operate a rocker arm, which advances a piston in a cylinder located within the melting pot, thus forcing

the molten metal up through a nozzle into the dies which are clamped in a framework directly above the nozzle. The machines in which compressed air is applied directly to the molten metal to force it into the dies, are of the valve type and the "gooseneck" type. These types differ in regard to details of the casting mechanism.

Air Pressures. — Most aluminum die-castings are produced with an air pressure ranging from 100 to 500 pounds per square inch, depending upon the type of casting. In casting certain metals and forms, pressures up to 1500 pounds per square inch are used. In the experience of one manufacturer parts made of pewter, Britannia metal, white metal, babbitt, etc., can be cast most satisfactorily without employing any air pressure and only a slight mechanical pressure.

Die-casting Dies. — Die-casting dies consist of two main metallic members analogous to the cope and drag of a sand mold. For zinc-, tin-, and lead-base alloys, these die members are usually made of low-carbon machine steel, while for aluminum castings, heat-treated chrome-vanadium steel is generally used. A steel recommended for die-casting dies by one of the makers of die-castings contains 2.25 per cent chromium, from 0.18 to 0.22 per cent vanadium, and from 0.30 to 0.50 per cent carbon. This steel is said to have much greater endurance in die-casting work than steel containing a smaller amount of chromium. It does not "check" or show minute cracks as soon as other steel would. From 80,000 to 100,000 pieces are said to be frequently cast in dies of this kind before any checking appears.

Each half of the die can be made of a great many component parts, but when assembled the dies must open and close in two sections. The cavities, holes, and other irregularities on the casting are produced by steel cores, which are usually made of the same kind of steel as the dies. The cores are operated by pinions that engage rack teeth cut on the cores, or in some cases by levers. Usually the cores are located in the die that is drawn away from the melting pot. The most descriptive names for the two die members are "ejector-die" for the movable member, and "cover-die" for the stationary one through which the metal is admitted to the die cavity.

Die-castings with Inserts. — Die-castings are often made with steel or brass inserts. These inserts are placed in the die at the time of casting, and the process involves no special feature except that the inserts are usually knurled or provided with some other means of anchoring them in the molten metal. The principal purposes of inserts are: (1) To lend added strength; (2) to furnish electrical or mechanical properties; and (3) to simplify assembly. A common practice is to cast inserts at specific points to provide bearing surfaces. This is often done in housings for magnetos. The magneto housings are also sometimes of such design that

special means for lubricating are necessary, and it is common practice to cast in oil-tubes, bent in almost any shape, to provide accessibility for lubricating.

DIE-CASTING MACHINE, AUTOMATIC. One of the modern types of die-casting machines is of the air-operated, gooseneck type and so designed that all movements in the machine cycle, and of the die are governed by a single lever, which engages the driving clutch. All subsequent movements of the machine and die are fully automatic. The machine can be stopped and reversed at any point, should some abnormal condition make this desirable. Standard zinc-base or aluminum-base metals obtainable from commercial sources are used in the machine.

The machine is driven by a special variable-speed motor which may be regulated for operating at four, six, eight, or twelve " shots " per minute. From this motor the drive is through back-gears and thence to a worm and worm-wheel, which drive a mechanism that affords an intermittent motion for advancing the die carriage to close the die and leaving it in this position while an elevating mechanism raises the gooseneck into place to deliver its " shot " of molten metal, allowing sufficient time for the metal to solidify before the die is opened and the finished casting ejected.

A number of castings may be made at " one shot." For example, in casting oil receiving cups a die having sixteen cavities gated together is used. The machine operates at the rate of 6 shots a minute producing 16 castings at each cycle, or 96 castings per minute. To cite another example, the die used for a certain type of clutch collar produces 6 castings per shot and operates 8 shots per minute. In this die there is a large core for each cavity to form the central hole in the clutch collar, and a small transverse interlocking core. These small cores are withdrawn by cam action and the large central cores are a fixed part of the die and are withdrawn with removable sections after the small transverse cores have been pulled back.

DIE CHASERS. The inserted cutters used in threading dies are commonly known as *chasers*. These chasers are rigidly fixed in some dies; in others, they are adjustable radially within a limited range for cutting threads slightly under or over the normal diameter of the die. The chasers on automatic or self-opening dies may be withdrawn far enough to clear the thread and thus avoid backing off.

DIE CLEARANCE. The amount of angular clearance ordinarily given a blanking die varies from one to two degrees, although dies that are to be used for producing a comparatively small number of blanks are sometimes given a clearance angle of four or five degrees to facilitate making the die. See also Punch and Die Clearance.

DIE CUSHIONS. The term " die cushions " is applied to some pressure attachments for drawing dies, especially the pneumatic type. See Pressure Attachments for Drawing Dies.

DIE-HOLDERS. The die-holders used for solid or non-opening dies may be of the rigid type, the floating non-releasing type, or the releasing type. For turret lathe and automatic screw machine work, the non-releasing type, which is free to move in a lengthwise direction a limited amount, is used extensively, although the releasing design is preferable under certain conditions. With this latter type the die is released or is not held against rotation after the thread has been cut to the required length. When the forward motion of the turret slide discontinues, the rotation of the screw thread draws one section of the releasing die-holder farther forward until the driving connection between the two sections disengages; the die then continues to revolve with the work as long as the latter continues to run forward. When the spindle is reversed the die starts to rotate backward with it, but this reverse movement is stopped automatically by the die-holder, and the stationary die is then backed off the screw as the spindle continues its reverse rotation.

The releasing type of die-holder (which is intended only for non-opening dies) is used when it is necessary to govern closely the length of the thread, as, for example, when cutting a thread close to a shoulder. If the reversal of the machine is controlled by the operator, as in a hand screw machine, a releasing die-holder should be used, because, if the machine is not reversed at the instant a die of the non-opening type reaches the limit of its forward travel, the thread may be stripped or the die broken when attempting to cut close to a shoulder. When the releasing type of holder is applied to the threading spindle of a multiple-spindle automatic screw machine, if the threading operation is completed before the other operations, the releasing device permits the die to revolve loosely until all the operations are completed.

DIELECTRIC. In electricity, the word *dielectric* indicates a non-conductor of electricity; a dielectric body, therefore, is an insulating body. The dielectric strength of a substance is the measure of its insulating qualities; the greater the dielectric strength, the better the material is as an insulating means. Dielectric strength is often indicated by stating the puncturing voltage for a thickness of 1 millimeter (0.0394 inch) of the material.

DIE-PRESSED CASTINGS. See Brass Forging and Hot-pressed Brass Parts; also Cold-pressed Castings.

DIE-PRESSED STEEL PARTS. See Hot-pressed Steel Parts; also Cold-pressed Forgings.

DIES. See type of die: Bending Dies; Blanking Dies; Burnishing Dies; Compound Dies; Curling and Wiring Dies; Drawing Dies; Embossing Dies; Follow Dies; Forming Dies; Gang or Multiple Dies.

DIES, CHROMIUM PLATED. See Chromium Plating.

DIES, DROP-FORGING. See Drop-forging Die Materials.

DIESEL ENGINES. The Diesel engine is an internal combustion engine which uses oil as a fuel, and which differs from other types of oil engines principally in that the fuel is introduced directly into the cylinder of the engine without previous gasifying or vaporizing, it being merely introduced in the form of a spray by an atomizer, and in that the engine requires no special ignition device. In the four-stroke cycle Diesel engine, therefore, air alone is drawn into the cylinder on the charging stroke, this air being compressed on the return stroke to a very high pressure — about 500 pounds per square inch — the result of the compression being that the air is heated to a high temperature and that the heavy oil injected into the air at the end of the stroke will be immediately ignited by it. The oil burns rapidly, but without explosion, the pressure exerted by the expansion due to the combustion of the oil producing the power impulse on the piston. Hence, the Diesel engine embodies two distinct features in which it differs from other internal combustion engines: the compression pressure is much higher than that in any other oil or gas engine, and igniting devices are not required, as the temperature of the compressed air is high enough to cause ignition of the oil.

Diesel engines may be broadly divided into two main types or classes: (1) The four-stroke cycle and (2) the two-stroke cycle engine. In both types of engines, the cylinder is filled with air at atmospheric pressure, the air being compressed by the piston until the pressure becomes about 500 pounds per square inch, and the compression raising the temperature to about 1000 degrees F. or more. At this instant a small quantity of oil fuel is forced into the very hot high-pressure air by means of a blast of air at still higher pressure. The oil is broken into a fine spray and its admission lasts only for about one-tenth of the downward stroke. During this short time the oil is burned in the hot air, producing a fairly constant pressure equal to the compression pressure at the end of the compression stroke.

The Diesel engine was invented by Rudolf Diesel, a German engineer, who secured the first patents in Germany on this engine in 1893, and who brought out the first successful engine in 1897 at the Augsburg Works, in Germany.

DIE-SINKING. Die-sinking is the process of forming an impression in a die (usually for drop forging). It is done by means of a die-sinking

type of milling machine in conjunction with hand chipping, filing, scraping, and " typing " if necessary.

A *die-sinking machine* is a type of vertical-spindle milling machine especially designed for the use of diemakers in milling out the impressions in drop-forging dies, etc., or for finishing recesses of circular or irregular shape. The simple type of die-sinking machine is largely manipulated by hand. In the operation of the Keller die-sinking machine, the cutter is guided over the work and in and out by means of a tracer point which follows the outline and contour of a model or master placed directly above the work. This master may be made either of plaster, cement, or wood. Only a slight pressure is exerted against the master by the tracer, while at the same time sufficient pressure is applied to the cutting tool. Rectilinear motions in three directions are provided, these motions being obtained by means of lead-screws which operate the different slides. Automatic feeds are provided both vertically and horizontally and there is a quick return in both directions for the horizontal movement. There is also a contouring or profiling movement by means of which a templet, or the ridges or grooves of a master, may be followed. When the work leaves the machine, it requires only a minimum amount of hand work for finishing.

Universal Die-sinker. A die-sinking machine known as a universal type, is so designed that both cherrying and straight die-sinking operations can be performed without any changes of set-up or any special attachments. The principal feature of the machine is an oscillating head by means of which an ordinary die-sinking cutter can be moved through a circular path, so that both roughing and finishing cherrying operations can be performed. A double binder provides for locking the entire oscillating head solidly to the column when the machine is to be used for ordinary die-sinking cuts in which the table elevating and transverse movements are employed. The machine is of the vertical type and has a knee supported by an elevating screw and sliding on vertical ways on the column. This knee carries a table which travels in both directions. The oscillating head is moved entirely by hand, through a handwheel on the front of the head. This machine will perform many types of cherrying cuts that are impossible on previous styles of the machine. For instance, by combining the rotary table feed and the oscillating cutter movement, it is possible to sink a spherical cut in the surface of a die and finish it ready for the polishing operation, all with the same cutter and without the use of an attachment.

DIE-SINKING, HUB METHOD. See Hub Method of Die-sinking.

DIE-SETS. A die-set consists of a punch holder, base, and pillars or guides for accurately holding the upper and lower members in alignment and as a complete unit which may readily be applied to a press. Die-sets

of this general type are manufactured in different sizes. They are so arranged that the user merely equips the die-set with whatever punches and dies or die openings, are required for a given operation.

DIE SLOTTERS. The openings in blanking dies are often machined in slotters especially designed for work of this class. A die slotter which represents a typical design is equipped with a short-stroke ram which can be set at an angle with the work table for machining the required amount of clearance. The table is circular and can be rotated for slotting circular openings. This circular table is mounted on compound slides which provide lateral and transverse feeding movements. The machine is of the column-and-knee construction, thus providing vertical adjustment for the work table. Blanking dies are also slotted on an ordinary column-and-knee type milling machine, by using a slotting attachment.

DIES, SECTIONAL TYPE. Certain advantages are claimed for the sectional stamping die over the solid die. In making repairs on dies of this type, it is only necessary to remove the damaged section and replace it with a new part. Other things being equal, this is a decided advantage. Furthermore, difficulties encountered in hardening a large solid die-block are not met with in the case of the sectional die; and each section can be accurately ground and fitted after hardening, thereby correcting errors due to distortion in hardening. In this way, each section can be made identical with every other. The accuracy that can be obtained in making sectional dies is also of importance.

Sectional dies are used extensively in the production of armature laminations for electric motors and generators, and are also applicable to the manufacture of other classes of stampings containing a large number of perforations. The only essential difference in design between the sectional lamination die and the solid die is that the punch holes in the sectional die are formed by sections arranged radially and accurately fitted and assembled on a plate.

DIE STEEL, COLD-DRAWING. See Wortle Steel under Tungsten Steel.

DIES, THREAD-CUTTING. Most external screw threads are cut by means of dies, because tools of this class not only cut threads rapidly but, when properly made, are capable of producing screws that meet most commercial requirements as to accuracy. Dies may be divided into two general classes, namely, those that are removed from the screw thread by being backed off or unscrewed, and those that may be opened so that the cutting edges clear the screw thread, thus permitting the die to be removed by traversing it over the work in a lengthwise direction.

The *non-opening dies* are capable in some cases of hand adjustment, but the object of this adjustment is to vary the size of the die. There are four types of non-opening dies in common use, which may be designated as (1) solid dies, or those that are rigid and incapable of any adjustment for varying the diameter; (2) flexible dies, or those that are split in one or more places and may be adjusted to some extent by compressing or expanding; (3) sectional dies, or those formed of two adjustable sections; (4) rigid adjustable dies of the chaser type, having inserted chasers that may be adjusted radially within certain limits either for maintaining a standard size or for varying the size slightly.

Self-opening Dies. — The different designs of *automatic* or *self-opening dies* differ principally in regard to the mechanism for opening the die chasers at the completion of a cut, the method of closing the chasers to the cutting position after removing the die, and the method of supporting the chasers against radial thrusts. Self-opening dies, in general, are formed of two main sections. One section, which includes the shank and inner part of the die body, is attached to the turret, spindle, or other part of the machine. These two main sections have a certain relative motion for opening the die or releasing the chasers from the work and for closing the chasers to the working position. This motion for operating the die may either be parallel to the axis of the die, rotary, or helical.

DIE TAPS. Die taps, also known as "long taper die taps," are used for cutting the thread in a die in one single operation from the blank and are supposed to be followed by a hob tap. The die tap is provided with a long chamfered portion and a short straight or parallel thread. If it is to be followed by a hob tap, the parallel portion should be slightly under the standard size so as to leave enough metal for the hob tap to remove to insure the correct size of the die. This difference in size should not only be on the top of the thread but in the angle of the thread as well, so that any inaccuracy in the lead of the thread may be taken care of. The difference must be very slight, as the hob cannot remove very much stock, as it has a very short chamfer and very small chip room for the stock removed. If this is not taken into consideration, the dies may be injured in the sizing operation. Die taps are very similar to machine nut taps and are made almost exactly in the same way.

DIETZEL PROCESS. The Dietzel process is an electrolytic refining process for separating silver and copper, the process consisting in dissolving both of the metals (as anode) in a weak acid solution of copper nitrate. This solution is then transferred to another vessel and the silver is precipitated by metallic copper, after which the copper is deposited electrolytically.

DIFFERENTIAL ACCUMULATOR. A hydraulic accumulator consisting of two cylinders of different diameters. The smaller cylinder is contained in the ram or plunger that fits into the larger cylinder. By the use of this machine very high pressures can be obtained.

DIFFERENTIAL BACK-GEARS. See Back-gears of Differential Type.

DIFFERENTIAL BLOCK OR HOIST. See Hoist.

DIFFERENTIAL BRAKE. A differential brake is a band brake in which both ends of the brake band are attached to arms on the brake lever, these arms having different lengths, so that the tension of the brake band can be varied by the operation of the lever. This brake is a good holding brake, but is not as suitable for regulating the lowering speed of a load as is a single-acting brake, because it is liable to give a jerky lowering action.

DIFFERENTIAL GEARING. This term is sometimes applied to planetary gear mechanisms, because of the differential motion or difference in the original motions which results in the final motion desired.

One of the important applications of differential gearing, at the present time, is found on automobiles. The object of transmitting motion from the engine to the rear axle through differential gearing is to give an equal tractive force to each of the two wheels and, at the same time, permit either of them to run ahead or lag behind the other as may be required in rounding curves or riding over obstructions. The axle is not formed of one solid piece, but motion is transmitted to the right- and left-hand wheels by means of separate sections, the inner ends of which are attached to different members of the differential mechanism.

DIFFERENTIAL GEAR SIZES. According to the S. A. E. recommended practice, a 10-tooth pinion should be used with an 18-tooth side gear, and an 11-tooth pinion with a 20-tooth side gear. All gears are to have $\frac{5}{7}$ pitch and a 20-degree pressure angle.

DIFFERENTIAL INDEXING. See Indexing.

DIFFERENTIAL MECHANISM ON GEAR-HOBBING MACHINES. In generating helical gears on hobbing machines without a differential, the required ratio which combines index and feed gears must be calculated with considerable accuracy as otherwise a serious error will result which will impair the accuracy of the gears. It frequently happens that the required ratio consists of prime numbers, especially when cutting right- and left-hand gears with one hob. To produce correct helical gears with their axes located parallel to each other, the errors for the right- and left-hand spirals must be the same, otherwise there will not be a bearing on the whole length of the teeth. If the hobbing machine has a differential, it

is not necessary to have a right- and left-hand hob for cutting any angle up to 30 degrees; on the contrary, better results are obtained by using only one hob for both right- and left-hand spirals because if there is any distortion in hardening, the right-hand hob will be different from the left-hand.

If the machine has a differential mechanism there is no variation in the helical movement when the number of teeth is increased or decreased or the feed is changed. On machines not provided with a differential mechanism, gears of the same pitch but with different numbers of teeth, must be calculated for separately, and the slightest change in the feed will require a separate calculation. A change in the formula must also be made, if right- and left-hand gears with the same number of teeth are cut with one hob. The differential is also of importance when cutting worm-gears with a taper hob. The belief of many mechanics that the ratios and errors obtained by formulas are alike for all hobbing machines, with or without differential mechanism, is entirely erroneous. There is a great difference between the two ratios. In the one case the ratio represents the value of the indexing and the helical movement, and the slightest change of the "driver," *viz.*, numerator, will cause a great error if the "driven," *viz.*, denominator, is not also changed in the same proportion. In the other case, *i.e.*, with the differential, the ratio obtained refers to the angle or helical movement only, and adds or subtracts itself automatically to or from the ratio of the indexing gears.

DIFFERENTIAL OR FLOATING LEVERS. Differential levers are utilized in some mechanisms to control, by the application of a small amount of power, a much greater force, such as would be required for moving or shifting heavy parts. These levers are commonly applied to mechanisms controlling the action of parts that require adjustment or changes of position at intervals varying according to the function of the apparatus subject to control. The initial movement or force may be derived from a hand-operated lever or wheel, and the purpose of the differential or floating lever is to so control the source of power that whatever part is to be shifted or adjusted will follow the hand-controlled movements practically the same as though there were a direct mechanical connection. A floating lever is so termed because it is not attached to fixed pivots and does not have a stationary fulcrum, but is free to move bodily, or to "float" within certain limits and in accordance with the relative forces acting upon the different connections.

DIFFERENTIAL WAGE SYSTEM. See Wage System, Differential.

DILATOMETER. A dilatometer is an apparatus for indicating and recording the volumetric changes in steel while it is subjected to heat,

in order to determine correct hardening temperatures. The physical properties of steel, such as hardness, tensile strength, elastic limit, and elongation, are affected by internal physical changes. When heat is applied to a piece of steel it expands due to changing of the internal physical constituents. By measuring the steel while being heated, the dimensional changes serve as a guide to what is taking place within the steel.

The most important critical transformation is that which occurs just before a piece of steel is ready for quenching to obtain full hardness. This is called decalescence, and its presence has been noted by loss of magnetism and by a cessation in the heating rate. Decalescence may be noted by measuring the volumetric changes. The mechanical means of measurement is known as the dilatometric method. It is claimed that this method is very accurate because it measures the changes throughout the mass of the metal.

DINKING DIE. A dinking die is used for cutting out formed shapes from leather, cloth, or paper. It is, practically speaking, a hollow punch or cutter having a sharp cutting edge shaped to correspond with the contour of the part to be cut. Dinking dies may be used either in a press or may be driven through the material to be cut by a mallet. The body of a dinking die is usually made of high-grade iron and the cutting edge, which should be of high-grade tool steel, is welded to the body. The outside bevel which forms the sharp cutting edge should have an angle of about 20 degrees. A good block for the cutting edge of the die to strike against can be made of seasoned rock maple. This block is laminated or built up of small strips which are glued or bolted together with the grain endwise. A block of this kind will give better results if kept damp by covering it with a wet cloth when not in use.

DIP BRAZING. A method of brazing metal parts by immersing them in liquid spelter solder. The spelter is contained either in a cast-iron tank or in a graphite crucible. See Brazing.

DIRECT CURRENT. A direct current is a unidirectional current; as ordinarily used, the term designates a practically non-pulsating current. A pulsating current is a current that pulsates regularly in magnitude; as ordinarily employed, the term refers to a unidirectional current. A continuous current is a practically non-pulsating direct current.

DIRECT-CURRENT COMPENSATOR. Same as Balancer.

DISCHARGE COEFFICIENT. In fans, the ratio between the actual quantity of air discharged and the theoretical quantity is the discharge coefficient. It may be taken at about 0.8 for the short outlet from a fan casing.

DISCHARGE RATE. In storage batteries, the discharge rate is the number of amperes that a battery will supply continuously for a given time, usually eight hours, three hours, or one hour. See also Storage Batteries.

DISCHARGING CAPACITY OF PIPE. See Pipe Discharging Capacity.

DISCONNECTING SWITCHES. The term "disconnecting switch" is applied to that class of lever switches which are used for the purpose of isolating oil switches, transformers, and like apparatus, or for sectionalizing bus-bars or transmission lines. Such switches may be of any voltage rating, but generally the name "disconnecting" is associated with switches of a voltage rating over that where it is safe to operate the switch by means of the ordinary handle; that is, voltages over 650. Disconnecting switches may be divided into two general classes; namely, indoor and outdoor. *Indoor disconnecting switches* for voltages of 1200 or less are mounted on slate bases. For voltages over 1200 and up to and including 3500, these switches are mounted on marble bases, and for all voltages over 3500, they are mounted on wet-process porcelain insulators which are, in turn, mounted on a sheet-steel or other metal base. *Outdoor disconnecting switches* are always mounted on porcelain insulators and of a type such as is used for supporting the line, these insulators being, in turn, mounted on channel-iron bases or some part of the transmission tower, or, in the case of the lower voltages, even on the ordinary wooden cross-arms.

DISHED DIE. A drop-forging die or any die used in the drop-hammer, is said to be "dished" when the force of the blows it receives causes the central part of the face to sink beneath the level of the remainder of the face. Dishing is usually traceable to a low grade of steel or to improper hardening.

DISH-PAN IDLER. This is a type of supporting idler pulley used in connection with belt conveyors for giving the required trough shape to the belt in order that it may retain the material carried by it. The dish-pan idler consists of three pulleys, one smaller in the center, and two larger, having convex spherical surfaces on the inside, mounted at the ends.

DISK BRAKE. A mechanical brake in which the braking force is produced by the frictional resistance between two or more flat disks.

DISK CLUTCH. A common design of disk clutch consists of a set of driving disks and a set of driven disks located alternately, so that each driving disk is between two driven disks. The driving disks may have key slots on their outer circumferences which are engaged by a key on the inner side of a driving drum, and the driven disks may be provided with lugs or key slots on the inner circumference for connection with the driven member.

Both the driving and driven disks of many clutches are metallic and run in oil. Steel disks about $\frac{1}{16}$ inch thick are often used. One set of disks may be of bronze, or possibly of sheet copper. One multiple-disk clutch which has been extensively used has alternate disks of steel and phosphor-bronze. These disks have V-shaped grooves instead of being flat, frictional contact being between the angular surfaces. In dry-plate clutches, one set of plates may be faced on both sides with asbestos fabric, or cork inserts may be used. See Clutches.

DISK GRINDERS. Disk grinding is employed principally for truing plane surfaces by holding the work in contact with a revolving abrasive disk. On the *single-spindle disk grinder*, which is the most common type, the work is simply held against the disk by hand or by placing a surface opposite to the one to be finished against an angle-plate on the table of the machine. The table may be at right angles or some other angle to the face of the wheel and fed toward it by manipulating a lever. Special fixtures are also employed for carrying the work to the disk.

The *vertical-spindle disk grinder* has a large disk wheel which revolves in a horizontal plane. In operating this machine, the parts to be ground are simply laid upon the revolving disk and are prevented from rotating with the disk by a cross bar. If the weight of the work is equal to three or four pounds pressure to the square inch of area to be finished, no additional pressure is required, but, in case it is much less than that, the output can be greatly increased by putting an additional weight on top of the work.

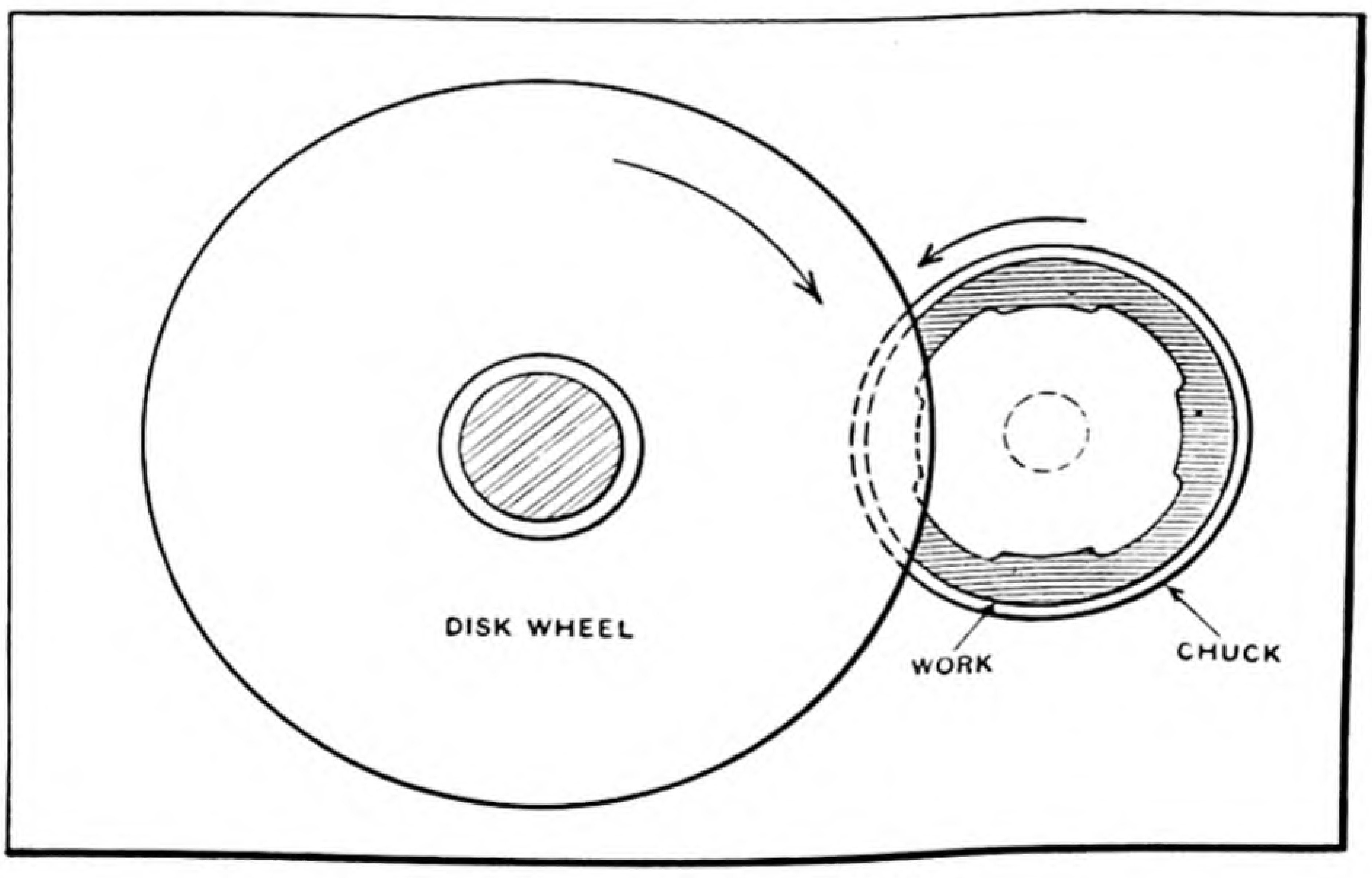
Such operations as grinding parallel sides of piston-rings, wrenches, cap-screw heads, and hexagon nuts are best performed on a *double-spindle disk grinder*. The two spindles are mounted in line, and carry an abrasive disk on the adjacent ends. The piece or pieces to be ground are placed in a work-holding device, advanced between the grinding disks, and ground in some machines by bringing the two disk heads together simultaneously, and in others by advancing only one head, the other one being in a fixed position. The table or work-holding device on both the single- and double-spindle machines is so constructed that an oscillating movement may be given to the work across the face of the grinding disk.

The *automatic double disk grinder* is for finishing parts having two opposite parallel sides of approximately equal area, such as piston-rings, electric iron plates, ball and roller bearing races, and gear blanks. In this machine the work is fed either from a magazine or by the operator into openings in a large continuously rotating wheel which carries the work past the disks.

DISK GRINDING ALLOWANCES. The amount of stock to be removed, the area of the ground surface, and its distribution are important factors in disk grinding. The removal of from 0.005 to 0.050 inch of stock

will usually "clean up" a surface. The following figures, taken from actual practice, represent allowances used in connection with one make of disk grinders: Drop-forged wrenches, from 0.008 to 0.015 inch; brass hexagon nuts, up to 2 inches in diameter, 0.015 inch; larger sizes, up to 0.030 inch; steel punchings, from 0.005 to 0.015 inch; cast-iron machine parts, from $\frac{1}{32}$ to $\frac{1}{16}$ inch; cast-brass machine parts, from $\frac{1}{64}$ to $\frac{3}{32}$ inch. The amount of stock that can economically be removed by disk grinding depends largely upon the nature of the material being ground. Cast metal is more easily ground than rolled or wrought material, and small thin castings are usually harder to grind than larger and thicker castings, owing to the greater density of the metal. When castings have a hard scale, it is often desirable to partially remove it before disk grinding. The hard scale is "broken up" either by grinding on vitrified wheels or by tumbling, sand-blasting, or pickling. The latter method is the best for forgings or hot-rolled material that has considerable scale.

DISK GRINDING BY ROTARY METHOD. The area that is in contact with the grinding disk is reduced, on some classes of work, by



Rotary Process of Disk Grinding

what is known as the rotary process. The diagram illustrates the principle. The part to be ground is held by means of a magnetic chuck, a faceplate, or a special fixture that is mounted in bearings and is free to rotate. The work table of the disk grinder is located so that the abrasive disk only makes contact with one side of the surface to be ground, as the illustration shows. The action of the grinding wheel rotates the work, so that the entire surface is ground as the result of the rotary motion. The rotary

method is employed when the surfaces to be ground are large and unbroken and considerable stock must be removed; when the work is thin and easily heated in grinding, or fragile and easily sprung; and also when an accurate plane surface is required.

DISK LOCATING METHOD. Comparatively small precision work is sometimes located by the disk method, which is the same in principle as the button method, the chief difference being that disks are used instead of buttons. These disks are made to such diameters that, when their peripheries are in contact, each disk center will coincide with the position of the hole to be bored; the centers are then used for locating the work. See also Button Locating Method.

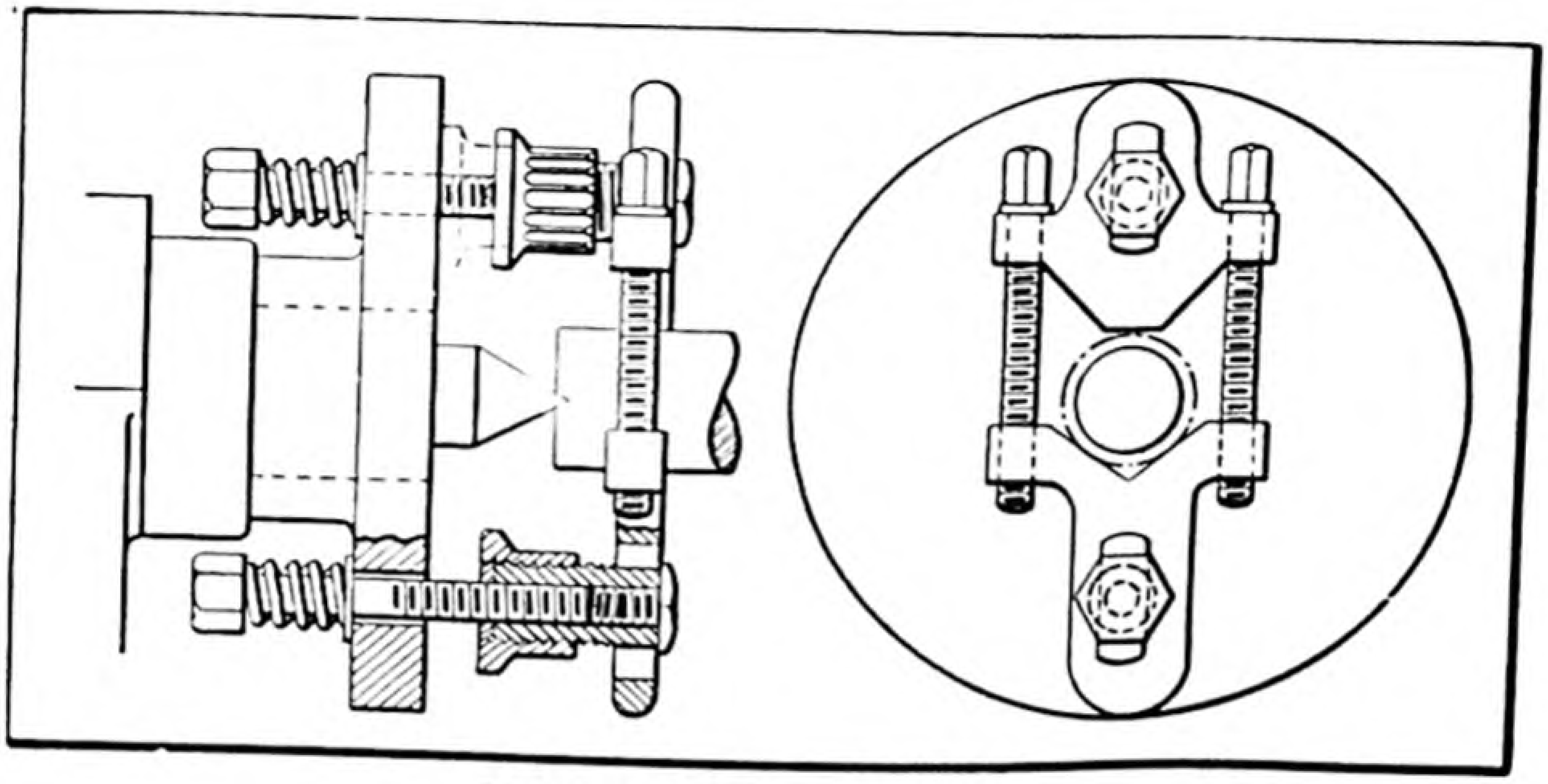
DIVIDING ENGINE. A linear dividing engine, which is believed to have been the first automatic machine used in the United States for graduating rules, was invented by J. R. Brown in 1850. This machine was not only fully automatic, but equipped with devices for correcting inaccuracies in the machine itself, such as might develop on account of wear.

DIVIDING HEAD. The dividing or indexing head is an attachment used principally on the universal milling machine for dividing circular parts into equal spaces or divisions, as when cutting gears, fluting milling cutters, etc. It is also used for imparting a rotary motion to cylindrical work (while the latter is fed axially by the longitudinal feeding movement of the table) for milling helical or spiral grooves. The dividing or indexing head is sometimes known as a *spiral head*. See Indexing Head.

DOGS OR DRIVERS. When a part is held between the centers of a lathe for turning, it is rotated by a dog or driver which is secured to one end of the work and engages a slot in the lathe faceplate. These drivers are also used for operations other than turning, in order to transmit motion from a rotating member to the work; for instance, when a piece is held between the centers of the dividing head of a milling machine, a dog is used to connect the work with the dividing-head spindle, thus rotating the part either when indexing or for generating a helical groove. Dogs or drivers are also used on cylindrical grinding machines for rotating parts held between the centers, and for many other purposes. To minimize the danger incident to the use of the ordinary lathe dog with its unguarded set-screw which tends to catch in the clothing, especially when filing, many safety dogs have been designed. See Equalizing Dog; also Compensating Dog.

Hold-back Dog. — The form of dog here illustrated is intended for driving a part when the outer end cannot be supported by the tailstock center of the lathe, as, for example, when boring a hole in the end of a cylindrical piece one end of which is supported on the headstock center and the other

end in a steadyrest. This dog has two bolts which pass through the faceplate. These bolts are supported by spiral springs at the rear of the faceplate, which give the required flexibility and permit the bolts to be so adjusted as to draw equally on both ends of the dog.



Holdback or Faceplate Dog

DOLOMITE. Dolomite is a natural carbonate of calcium and magnesium generally used as a flux in blast furnaces and in the basic bessemer process. Dolomite, like other fluxes, must form with the gangue an ash and slag that will melt at about the same temperature as the iron, which will become fluid enough to be drawn off, and rich enough in lime for the desulphurizing reaction.

DOUBLE-ACTION DIE. See Drawing Dies.

DOUBLE-ACTION PRESSES. The double-action type of power press is extensively used for drawing cylindrical or other circular shaped parts from flat sheet-metal stock. There are two slides which are operated independently; hence, the name *double action.* The outer slide is for operating the combined blanking die and blankholder of the double-action drawing die, whereas the inner slide operates the inner plunger or die which draws the part to shape. These slides may be actuated either by cranks, cams, or a toggle mechanism. The presses having a crank form of drive are much used in the manufacture of seamless drawn articles of comparatively shallow depth. The crank type of construction permits of much faster and smoother operation than is practicable with cam-driven presses.

Double-drawing presses differ mechanically from the ordinary double-action press in having three instead of two moving slides, and, therefore, might appropriately be called triple-action presses. The principal reason for this design is to save time and increase production by making two drawing operations on a single article with one stroke of the press or to

draw and redraw, or redraw twice, in a single operation. This type is particularly adapted for articles that require more than one drawing operation to reduce them to the required dimensions.

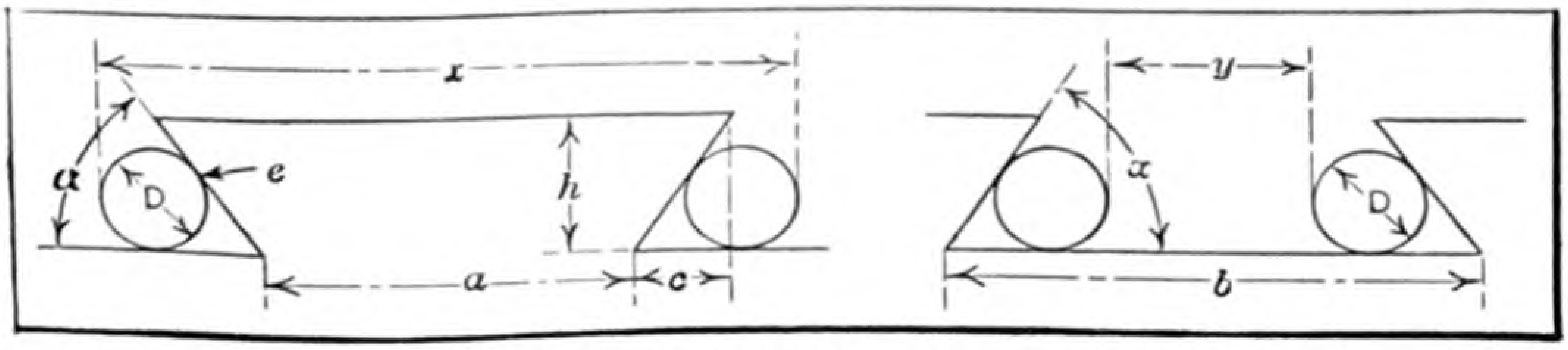
DOUBLE-ARCH FURNACE. This is a furnace in which the grate is divided into two parts by a wall. The two fireboxes thus formed connect with a common combustion chamber by way of a brick arch at the rear of the bridge wall. The advantage obtained by the arrangement is that the two furnaces may be fired alternately.

DOUBLE-CONTACT CAM. A cam in which the follower has two points of contact, one on each side of the cam. This provides a positive motion for the parts connected to the follower.

DOUBLE-POLE CIRCUIT-BREAKER. A circuit-breaker used on two-wire direct-current and single-phase alternating-current lighting and power circuits, and on three-wire direct-current circuits. In the latter case, the circuit-breaker is equipped with an over-load device on each pole, while, for the other conditions, an over-load device on one pole is sufficient.

DOVETAIL JOINT. See Joints used in Patternmaking.

DOVETAIL SLIDE. This is a type of slide used extensively in machine construction. It has angular sides which interlock with the grooved part



Cylindrical Rod Method of Measuring Dovetail Slides

of the mating base or slide. As a general rule, a gib is inserted between the slide and the grooved member, to provide means of taking up all play.

Dovetail slides which must be machined accurately to a given width are commonly gaged by using pieces of cylindrical rod or wire and measuring as indicated by the dimensions x and y in the accompanying illustration. In order to obtain dimension x for measuring male dovetails, add 1 to the cotangent of one-half the dovetail angle α, multiply by diameter D of the rods used, and add the product to dimension a. To obtain dimension y for measuring a female dovetail, add 1 to the cotangent of one-half the dovetail angle α, multiply by diameter D of the rod used, and subtract the result from dimension b.

DOVETAIL SLIDE ANGLES. The angle α (see illustration accompanying preceding paragraph) does not conform to any fixed standard and

varies in practice, usually from 45 to 60 degrees. The 60-degree slide or dovetail is easier to make and fit accurately than a smaller angle, such as 45 or 50 degrees, and consequently, the 60-degree slide is preferred by most manufacturers. Any wedging action tending to open a dovetail slide, is greater with the 60-degree angle than with smaller angles, the ratio being 173 to 100 for 60-degree and 45-degree slides, respectively. A 45-degree slide, however, requires greater width when properly designed than a 60-degree slide, which usually is important since the slide width is somewhat limited. Within given limits a stronger 60-degree slide can be designed than one of 45 degrees, and the somewhat greater wedging force tending to open the 60-degree slide is ordinarily of little practical importance.

DOWEL PINS. Dowels are used either to retain parts in a fixed position or to preserve alignment. Under normal conditions a properly fitted dowel is subjected to shearing strain only, and this strain occurs only at the junction of the surfaces of the two parts which are being held by the dowel. It is seldom necessary to use more than two dowels for holding two pieces together and frequently one is sufficient. For parts which have to be taken apart frequently, and where driving out of the dowels would tend to wear the holes and thus loosen the dowel, and also for very accurately constructed tools and gages which have to be taken apart, or which require to be kept in absolute alignment, the taper dowel is preferable. As applied to average machine work, the taper dowel is most commonly used but the straight dowel is given the preference on tool and gage work, except where extreme accuracy is required, or where the tool or gage is to be subjected to rough handling, and knocking about would be likely to shift the doweled parts.

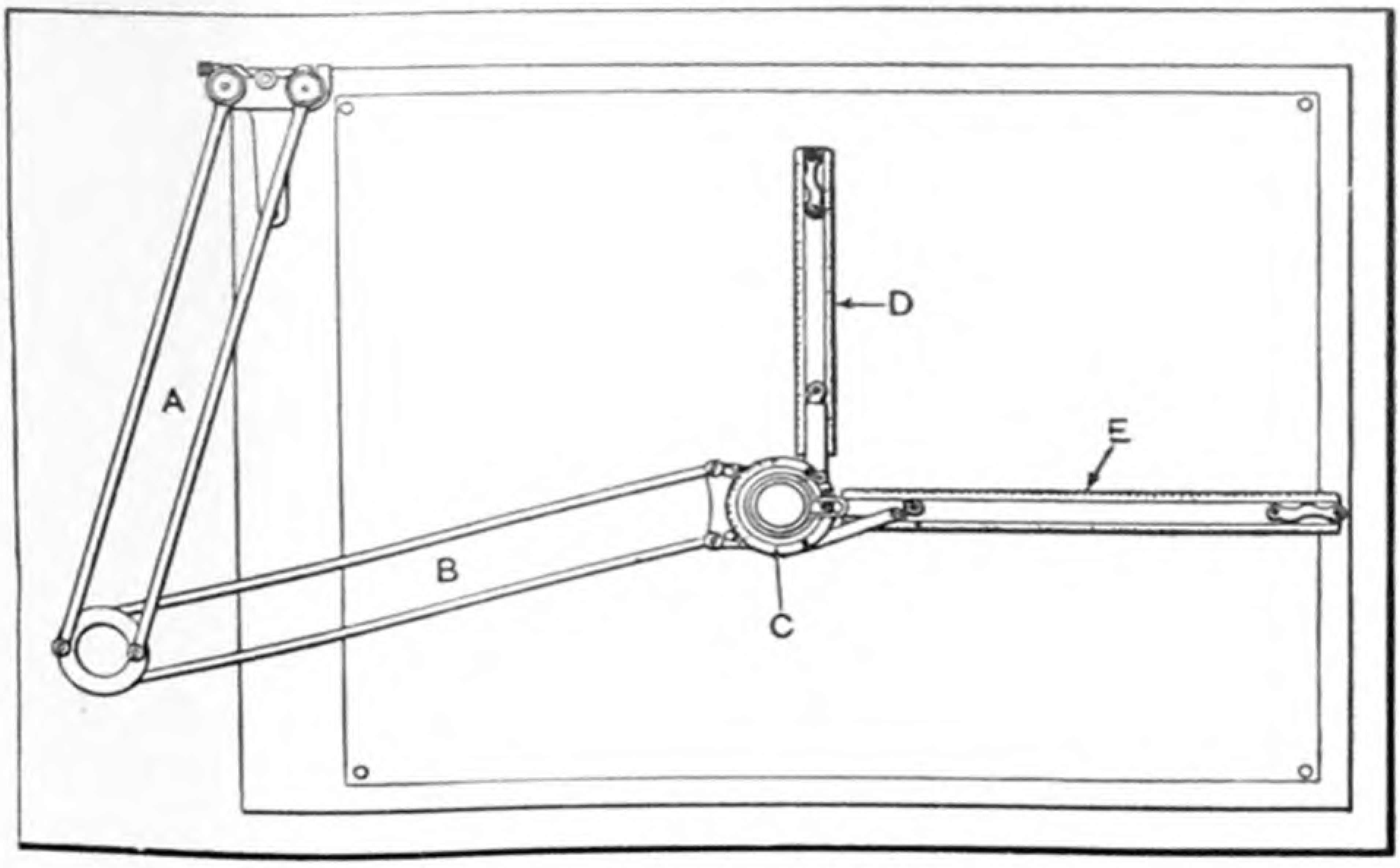
DOWELS, EMBOSSED. See under Rivets, Cold-formed.

DOYLE RULE. The Doyle rule which follows is employed for finding the board measure of logs: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

DRAFT. See Forced Draft; Induced Draft; Mechanical Draft.

DRAFTING MACHINES. The device known as a *drafting machine* is employed to facilitate the making of drawings, by taking the place of T-square, triangles, protractor, and scale. It consists of two parallelograms *A* and *B* (see illustration), a protractor *C*, and two scales *D* and *E*, set at right angles to each, these scales being used as ruling edges. The two parallelograms are joined together in such a way that when the upper

end of one of them is fastened to the drawing-board, as indicated, the protractor and ruling scales will have a parallel motion on the drawing. This arrangement permits the zero of either of the ruling edges to be instantly placed on any point of the drawing, so that lines may be drawn and measured off at the same time. The protractor, placed where the two scales or rules join, permits the square formed by the rules to be set at any angle, and after that the ruling edges may be moved about the board with the same parallel motion as when set as shown in the illustration. This feature



Universal Drafting Machine

is of great importance in structural work, where a great many parallel lines must be drawn at angles other than horizontal or vertical. Drafting machines are made for practically all kinds of applications, and for both horizontal and vertical drawing-boards.

DRAFT ON PATTERNS. Draft is a tapering of all the vertical faces of a pattern to permit its removal from the sand without excessive rapping on the part of the molder. There is no rule fixing the amount of draft to give a pattern, but it is a good plan to allow as much draft as possible without distorting the pattern; this may vary from $\frac{1}{32}$ to $\frac{3}{16}$ inch or may even be as much as $\frac{1}{4}$ inch per foot of height. The draft always extends away from the pattern face, or larger side of the pattern. Very small patterns and those of larger sizes to be used in molding machines are often made without draft.

DRAW-BAR PULL. This term applied to locomotives represents the amount of power actually exerted at the draw-bar, and it is somewhat less than the tractive force. See Tractive Force.

DRAW-BENCHES. Two types of machines are generally used for drawing shafting and screw stock. The first of these is known as the "straight draw-bench," on which a straight rod is drawn through the die by means of tongs on a head which travels in a straight line along the draw-bench, power being furnished by an endless sprocket chain or by hydraulic pressure. The second type is the bull-block machine, on which the rod is in the form of a coil that is carried on a reel at one end of the machine; the end of this rod is pointed and threaded through the drawing die, and gripped by tongs carried on a second reel, which rotates in such a way that the rod is drawn through the die and wound up on the second reel.

The draw-benches, by means of which the tubes are drawn, are of different sizes for working on heavy or light stock. The mechanism of the draw-bench is simple and powerful. A typical design that handles tubes up to 20 feet in length consists of a "bench" about twenty-five feet long, within which is an endless sprocket chain of very heavy pattern that passes over a sprocket at the driving end and an idler at the head of the machine. The drive is through compound gearing to the sprocket at the end of the draw-bench, and the sprocket chain runs continuously. The speed at which the chain travels is about sixty feet a minute for the smaller sized machines, but slower in the larger machines. At the forward end of the machine, the frame runs into a very heavy head, against which the dies are held when drawing the tubes. Supported centrally in the head is a steel plate with a clearance hole large enough for the tubes to pass through. Directly against this clearance plate, the dies are held loosely while the tubes are pulled through them. This drawing operation is accomplished by a carriage, drawn away from the head of the machine by means of a hook that may be caught between the chain links. On the forward end of this carriage is a pair of gripping jaws that catch the end of the tube when it is started and pull it through the die. At the end of the stroke, the hook is lifted out of the chain and the carriage returned by hand.

DRAW-FILING. When a file is held at each end and the motion is sidewise rather than in a lengthwise direction of the file, this is known as *draw-filing*. With this method of filing, the metal is removed more slowly than by cross-filing, provided the same kind of file is used in each case. The surface is left smoother, however, if the draw-filing is properly done, as the scratches are closer, owing to the shearing or shaving cut taken by the file teeth.

DRAW-IN CHUCK. This is a collet type of chuck generally used on tool-room lathes, turret lathes, bench lathes, and similar machine tools, for holding bar stock or tools. The end of the chuck is split so that it can be forced together, to clamp over the stock or tool held in it. The

outside of the end is conical, and fits into a conical chuck closer, so that by pulling back the chuck, the chuck closer forces the split chuck to clamp.

DRAWING DIES. Drawing dies are used for drawing parts from flat stock into cylindrical and various other shapes. There are several different classes of drawing dies, including plain drawing dies, combination dies, double-action dies, and triple-action dies. The *combination type* of die is one in which a blanking die and either a drawing or forming die are combined so that the blank is cut out and drawn or formed to shape in one stroke of the press. Owing to the construction, a combination die can be used in a single-action press, or one having a single slide. In most cases, articles made in combination dies are in the form of shallow cups, etc., such as can tops and bottoms, pail bottoms and a variety of similar parts which frequently are not over $\frac{1}{4}$ inch in depth. Dies of this class are also used for deeper articles, such as boxes and covers for blacking, salve, tobacco, etc., with depths up to about one inch.

Double-action dies are so named because the blanking and drawing punches have independent movements which are derived from the two slides of a double-action press; hence, the name of the die, in this case, indicates the type of press in which it is used. A *triple-action die*, as the name implies, is one having three independent movements. This class of die is used to produce articles requiring three operations, such as cutting or blanking, drawing, and stamping or embossing. Triple-action dies are especially adapted for such work as drawing and embossing lettered covers for blacking boxes, baking powder cans, covers for lard pails, and also for articles such as seamless sardine boxes, etc.

After cups have been drawn in either a plain or double-acting drawing die, what are known as *redrawing dies* are often used to reduce the diameters of these comparatively shallow cups, and at the same time increase the depth or length, thus forming a shell. Some redrawing dies do not differ essentially from an ordinary plain drawing die.

DRAWING SIZES. While the practice differs to some extent in different manufacturing plants, it is fairly common practice to use drawings 24 by 36 inches in size as the standard sheet. For smaller work, this is divided into half-sheets, 18 by 24 inches; quarter-sheets, 12 by 18 inches; and eight-sheets, sometimes called "sketching" sheets, 9 by 12 inches. These dimensions of standard sheets have been adopted because it is possible to obtain rolls of drawing paper, tracing cloth, and blueprint paper in such widths that sheets of the sizes mentioned can be conveniently cut from them with a minimum of waste.

DRAWING STEEL. Steel is "drawn" or tempered by reheating it after hardening to some temperature below the critical temperature

range and then cooling the steel. This heat-treatment is often referred to as drawing, but the term tempering is preferable. The object of tempering cutting tools is to reduce the brittleness of the hardened steel and increase its toughness sufficiently to withstand the shocks incident to working conditions. See Tempering.

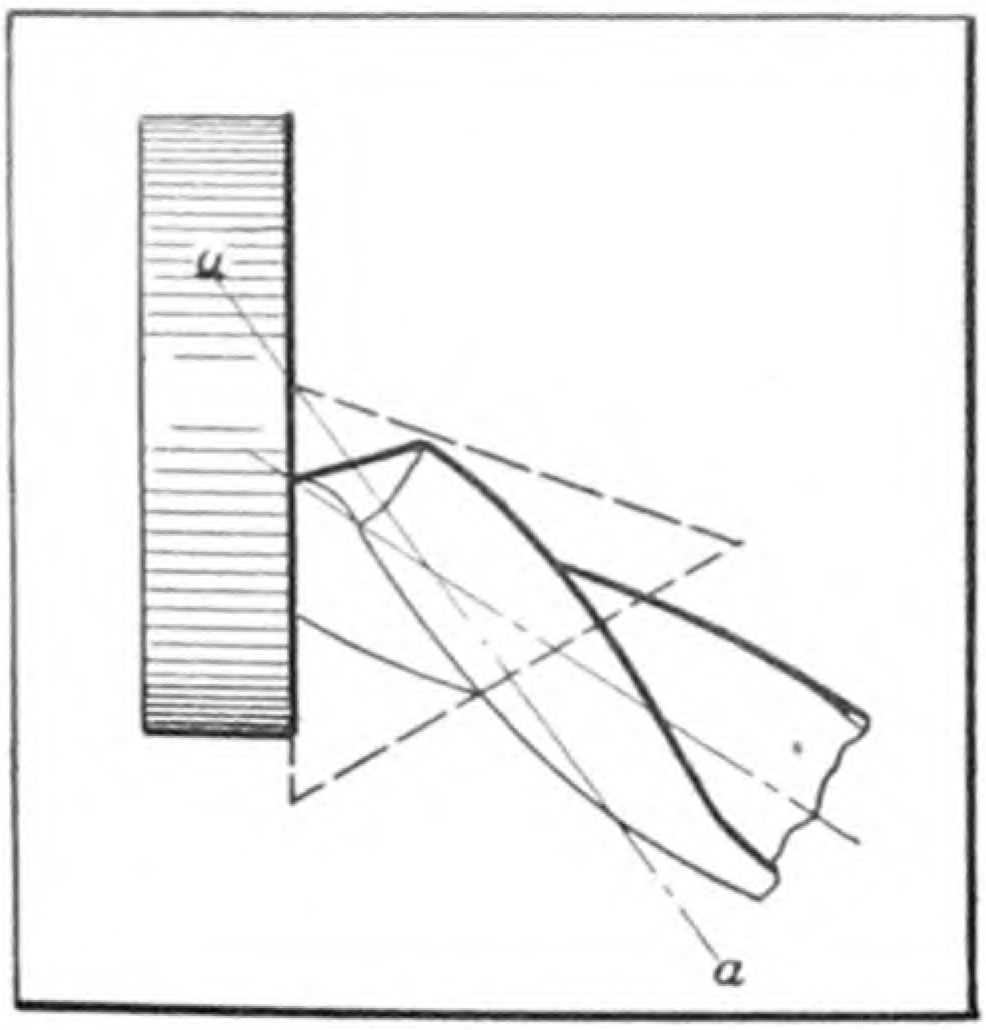
DRILL AND WIRE GAGES. There are three well-known standards for twist drills and steel wire that are commonly used at the present time. These are the Stubs steel wire gage, the gage used by the Standard Tool Co. and the gage used by other leading manufacturers, such as the Morse Twist Drill & Machine Co., and the Brown & Sharpe Mfg. Co. The latter has been termed "the manufacturers' standard." The Stubs steel wire gage is used for measuring steel wire and drill rod, but it is not used as much in the United States at the present time as in the past. The gage used by the Standard Tool Co. was originally adopted for drill sizes in the United States, but other manufacturers changed the numbers corresponding to certain sizes, while the Standard Tool Co. retained the original numbers, but interpolated half sizes in order to agree as to the actual diameters of drills furnished by other manufacturers. The Standard Tool Co.'s gage agrees with the "manufacturers' standard" for the sizes from Nos. 1 to 60, inclusive, but does not agree with the Stubs steel wire gage. From Nos. 61 to 80, inclusive, it agrees with the Stubs gage, half sizes being omitted. It also agrees with the manufacturers' standard, as far as the diameters used are concerned, but the numbers corresponding to given diameters are different.

DRILL GRINDING. As the angle between the cutting edges of a drill is decreased, the pressure required for feeding the drill downward through the metal, becomes less, but the length of each cutting edge is increased, with the result that more power is required to turn the drill. An included angle of 118 degrees (59 degrees between the cutting edge and axis) is believed by some to equalize the thrust and torsion to the best advantage, while others advocate more acute angles.

Theoretically, the *clearance* of a drill should be just enough to permit the drill to cut freely, because excessive clearance weakens the cutting edges. A clearance angle of 12 degrees at the periphery of the drill, with a gradual increase toward the center is recommended for average conditions. When soft metal is to be drilled and heavier feeds are possible, the angle of clearance may be increased to 15 degrees, whereas for hard material, such as tool steel, for example, the amount of clearance should be diminished, as a fine feed must necessarily be used and a strong cutting edge is required.

DRILL GRINDING MACHINES. In order to obtain the best results from twist drills, they should be ground in specially-designed drill grinding

machines. The two cutting edges should have the same inclination and come into contact with the work throughout the entire length at the same time, and the clearance surface back of the cutting edge should vary from the point of the drill, where it is greatest, to the periphery, where it is the least acute. A method of obtaining this varying clearance, which is commonly employed in connection with drill grinding machines, is illustrated by the accompanying diagram. The rotation of the drill, when grinding, is about an axis *a–a* which is inclined from the face of the grinding wheel somewhat less than the axis of the drill. When a drill is ground in this way, the end is given a conical surface, the apex of the cone being above the point of the drill, as indicated by the dotted lines.



Drill Grinding

An automatic type of drill grinding machine has been developed which is automatic in operation, after the drill is placed in the chuck of the machine, and the latter is started; the machine continues to grind the "lips" of the drill until sharp cutting edges are obtained, when the operator stops the machine and removes the drill.

DRILL HEADS. Single-spindle drilling machines are sometimes equipped with attachments commonly known as *drill heads,* which are equipped with two or more spindles for drilling, simultaneously, whatever number of holes the head is designed for. A drill head of typical construction has a taper shank which enters the drilling machine spindle and drives all of the spindles of the attachment through spur gearing. Drill heads may be divided into two general classes, namely, the adjustable and the non-adjustable types. The adjustable heads vary in regard to the kind or range of adjustment that is possible. The straight-line adjustable drill head has all of the spindles in the same vertical plane, the adjustment in this case enabling the center-to-center distances to be varied, according to the work. A drill head having radial adjustment is a type of multiple-spindle drilling attachment which may be adjusted for drilling or tapping operations on circles of various diameters.

DRILLING DEEP HOLES. For drilling deep holes, a rotary motion should be given to the work and a feed motion to the drill; then if the point of the drill does not run true, it will be carried around by the work in a circle, thus tending to bend the drill in various directions. The drill is

by this action forced back into the path of " least resistance," as it is evident that the bending action, being exerted on the drill in all directions, will tend to force the point back in alignment with the axis of the work where there will be no bending action.

DRILLING MACHINES. Drilling machines or " drill presses," as they are often called, which are used for drilling holes in machine parts, are made in many different types designed for handling the various classes of work to the best advantage, and the different types are also built in a great variety of sizes, because the most efficient results can be obtained with a machine that is neither too small nor too large and unwieldy for the work which it performs. Drilling machines are classified in various ways.

The *upright drilling machine* is the type most commonly used, and the name applied to this class indicates that the general design of the machine is vertical, and also that the drill spindle is in a vertical position. All drilling machines, however, which have vertical spindles and are arranged vertically, are not classified as upright drills.

The *radial drilling machine*, which is another very common design, has a vertical spindle, which is carried by an arm that may be swiveled about a vertical column. The distinguishing feature of this machine, however, is the radial adjustment of the arm about the column, which adjustment, in conjunction with the traversing motion of the drill-spindle head along the arm, makes it possible to readily locate the drill in any position within the range of the machine, which is a decided advantage when drilling heavy parts that could not be shifted easily. Machines of this class, therefore, are said to be of the radial type, because the radial or swiveling adjustment of the arm is the characteristic feature.

The *sensitive drill* is another vertical or upright design, but it is classified as sensitive because it is a comparatively small machine of light construction, which possesses sensitive qualities which are of value in drilling delicate work.

The *multiple-spindle type*, which is built in both vertical and horizontal designs, is given a name which is self-explanatory. Some drilling machines equipped with multiple spindles are known as *gang drills*. The term " gang drill " is generally applied to a vertical design practically consisting of several machines combined in one unit, and with the spindles all in the same vertical plane. Machines of this general design are also referred to as multiple-spindle drills, by many manufacturers. Drilling machines, however, having spindles which are arranged in a group so that they may be adjusted according to the respective positions of the holes, whether in a straight line, on a circle, or irregular as to location, are especially known as multiple-spindle types.

Some drilling machines having more than one spindle are named according

to the number of spindles, as, for example, a four-spindle sensitive drilling machine, etc. In other cases, a special design of machine having several spindles is classified according to the work for which it is intended, as, for instance, a staybolt drilling machine, a locomotive frame drilling machine, a rail drilling machine, etc. Very heavy and powerful drilling machines of the vertical or upright type are also referred to as "high-duty" or "heavy-duty" type drilling machines, because they are capable of very rapid drilling.

Some drilling machines are equipped with a turret which carries the necessary tools, and is indexed to locate these tools in the working position the same as the turret of a turret lathe. There are two general types of these machines: one has a turret which revolves about a horizontal axis with the tools in a vertical plane, and the other, a turret which revolves about a vertical axis. Machines of this type are adapted to work requiring successive operations, such as drilling, reaming, counterboring, etc.

DRILLING MACHINE SIZE. The size of an upright drilling machine is equal approximately to twice the distance from the drill spindle to the column. A 28-inch drilling machine, for example, will drill to the center of a 28-inch circle or possibly to the center of a 29-inch circle. The size of a radial drilling machine represents the maximum distance from the column to the center of the spindle or the greatest radius at which the drill spindle can be set.

DRILL PRESS. This term is often applied to metal drilling machines in general, evidently because the drill is pressed or forced through the metal as it revolves. See Drilling Machines.

DRILL ROD. Small diameter, high-carbon tool-steel rods are generally referred to as *drill rod*. Drill rod is either polished or unpolished. Carbon-steel drill rod is kept in stock by steel manufacturers in all sizes, from $\frac{1}{64}$ to $1\frac{1}{2}$ inch, by 64ths, and, in addition, the standard "letter" and "number" sizes for drills are available. Square drill rod is kept in stock for all sizes between $\frac{1}{16}$ and $\frac{1}{2}$ inch, by 32nds. High-speed steel drill rod is kept in stock from $\frac{1}{16}$ to $\frac{1}{2}$ inch, by 64ths, and for all "letter" drill sizes, and for "number" drill sizes from 1 to 52, inclusive. Some of the steel manufacturers work to a limit of 0.00035 inch above and below the specified sizes for diameters smaller than 1 inch, and to a maximum limit of 0.0005 inch above or below the specified size, for sizes between 1 inch and $1\frac{1}{2}$ inch.

DRILLS. A number of different tools used in the machine shop are classified under the head of drills. The most common of all for ordinary drilling is the *twist drill*. Special drills have also been developed for drilling square, triangular, or polygonal holes, and there are special forms for deep-hole drilling.

Drawn wire (drill rod) is used for smaller sizes of drills — so-called *wire gage* sizes — and the outside is not turned. Twist drills for drilling " from the solid " are provided with two grooves or flutes. For special purposes a three-fluted drill is sometimes used for enlarging a hole made by a smaller drill, or for finishing cored holes. The lead of the helix of the groove or flute in twist drills is either the same for the full length of the groove (constant-angle drills), or the lead is gradually increased from the point towards the shank (increased-twist drill).

Flat Twisted Drill. — The flat twisted drill is made from a flat bar of steel and is twisted while hot in a special machine designed for this purpose. Flat twisted drills are strong and capable of very rapid drilling. Forming the drills by twisting the flat stock leaves large flutes, so that there is nearly 60 per cent more clearance space for the chips than in the ordinary fluted drill. This reduces the amount of operating power required, owing to the relief from the clogging of the chips in a deep hole.

Straight-fluted Drills. — A drill which has two straight flutes instead of the helical or spiral form, may be used to advantage for drilling brass or thin sheet metal. Ordinarily twist drills, owing to the acute angles of the cutting edges, tend to " dig in " or catch, especially when coming through the lower side of a thin plate; this difficulty, however, may be largely, if not entirely, overcome by using a straight-fluted drill, as the cutting edges have not the rake or slope common to twist drills. The name *farmer's drill* is sometimes applied to the straight-fluted form.

Drill Shanks. — Twist drills $\frac{1}{4}$ inch in diameter and larger are made with either straight or taper shanks, the latter being the more common. The taper of the shank is almost always the Morse standard. A short neck is provided between the grooved part of the drill and the shank. Smaller sizes of drills are, in nearly all cases, made with straight shank only, and have no neck. The shank and the fluted part on these smaller sizes of drills are of the same diameter. If a drill is too small to permit inserting it directly in the spindle, a socket or sleeve is used which fits the spindle and has a taper hole corresponding to the size of the drill shank. The drill is caused to rotate with the spindle or socket, principally by the friction between the shank and the socket, and any slipping is prevented by a flat end or tang on the shank which engages a cross-slot at the end of the taper hole. The drills used in chucks ordinarily have straight shanks instead of the taper form.

Drill Sizes. — Commercial drill sizes are expressed either by giving the drill diameter or by using letters or numbers representing diameters of the smaller sizes. One type of gage for measuring drills with numbered sizes has the number of the drill indicated by the number of the hole in which the drill fits. The difference between the diameters of consecutive

sizes represented by this gage only varies from 0.001 to 0.008 inch, so that almost any diameter between the smallest and largest size can be obtained. The decimal equivalents for each number are stamped on the back of the gage shown. Another common form of gage, known as the *jobbers' drill gage*, has a series of holes which vary in diameter from $\frac{1}{16}$ to $\frac{1}{2}$ inch, the diameters increasing successively by sixty-fourths. The sizes of the different holes are expressed by common fractions which are stamped on the gage. The letter size drills are made in sets of twenty-six, or from A to Z, and have a difference between consecutive sizes varying from 0.004 to 0.014 inch.

DRILLS, ANGULAR HOLE. Special drills have been developed for drilling square, hexagonal, octagonal and other angular holes. Tools for this work have been made in several different forms, but the principle of operation is to rotate a drill of special form in a guide which has the same shape as the hole to be cut. The drill is mounted in a special floating chuck which allows sufficient movement so that the cutting edges of the tool can generate the required shape of hole. The lands of the drill successively come into contact with the guide and act as cams which cause the cutting edges of the drill to follow the desired path. Drills used for this work only cut with the front edges, there being no cutting edges along the side. These angular drills have been used successfully for drilling steel, cast iron, brass, aluminum and various non-metallic substances. Ordinarily, in using tools of this type, it is advisable to first drill a round hole which is about $\frac{1}{8}$ inch smaller in diameter than the width across the sides of the square, hexagonal, or other hole. By thus removing most of the metal, the angular drill may be operated at higher speed and with less strain on the tool.

DRILL SPEEDING ATTACHMENT. In drilling small holes on a machine which is not arranged for high speeds, the drill revolves too slowly and the operation requires much more time than would be necessary if the drill were operated at the proper speed. Many drilling machine attachments have been designed for increasing the speeds of small drills. These are often called "drill speeders." These attachments are applied to the end of the drill spindle, and, by means of suitable gearing, the auxiliary spindle in which the small drill is held is rotated much faster than the main spindle of the machine.

DRILL SPEED REGULATOR. This is an attachment which is applied to the end of the drill spindle for driving different sizes of drills at the correct speed by automatic regulation. A different collet is provided for each size of drill which is used, and the speed changes are obtained by having a driver on each collet located in a different position, so that each

one engages the proper gears in the head. With this arrangement, the speed is regulated automatically in accordance with the size of the drill.

DRILLS, PORTABLE AIR-DRIVEN. Pneumatically-operated drilling machines of the portable type are not only used for drilling, but for reaming, tapping, flue rolling, wood boring, and as motors, especially for driving portable tools such as valve-setting and cylinder-boring machines in locomotive repair shops. Pneumatic or "air" drills, as they are often called, are made in reversible and non-reversible designs. The type commonly used is driven by an air motor of the reciprocating piston type, which is contained within the casing of the machine. The pistons are single-acting and impart rotary motion to the crankshaft by suitable connecting-rods. This crankshaft, in turn, drives the main spindle of the machine through gearing which reduces the speed and gives the necessary increase in power. What is commonly known as the *close-quarter air drill* is designed for use in corners or narrow places where a drilling machine of ordinary size cannot be used.

DRILLS, PORTABLE ELECTRIC. A portable electric drill is a compact semi-enclosed electric motor in combination with mechanical features so designed and constructed as to be applicable for drilling or reaming in wood or metal more or less intermittently. Portable electric drills are generally listed according to their drill capacity, and sometimes this is definitely specified as the maximum size drill that the motor has sufficient power to drive through steel. Many electric drills have "universal motors" built to operate on either direct or alternating current, the standard frequency for alternating current being 60 cycles. Some drills are built to operate on 180 cycle current for use where a frequency changer is installed; the advantage claimed is that the weight of the various size drills is about one third that of corresponding 60 cycle current tools. The standard $\frac{1}{4}$-inch capacity drills weigh about 6 pounds, the $\frac{3}{8}$ inch about 12 pounds, the $\frac{1}{2}$ inch from 12 to 21 pounds, the $\frac{5}{8}$ to $\frac{7}{8}$ inch inclusive from 20 to 24 pounds, and the 1 inch about 35 pounds. Electric drills are made either standard, light duty, or heavy duty, and the weight varies accordingly. Electric drills are equipped with a drill chuck for holding straight shank drills, or a spindle with a standard tapered hole for taper shank drills. The drill chuck or drill spindle is usually driven by reduction gearing from the motor armature shaft. These spindles are located so as to provide what is termed straight-line or close-quarter construction, so as to permit the drilling of holes as close to a wall as possible.

DRIVE PIPE. The name applied to a pipe used in conjunction with a hydraulic ram. See Hydraulic Ram.

DRIVERS OR DOGS. See Dogs or Drivers.

DRIVING FIT. When a plug or a shaft is made slightly larger than the hole into which it is to be inserted and the allowance is such that the parts can be assembled by driving, this is known as a *driving fit.* Such fits are employed when the parts are to remain in a fixed position relative to each other. The allowance for a driving fit depends upon the length of the bearing surface, the diameter of the hole, the smoothness of the surfaces and the thickness and kind of metal surrounding the hole.

DROOPING CHARACTERISTIC. This is a term used in connection with electrical machinery when the voltage varies inversely with the load.

DROP FORGING. Forgings produced in dies by a falling hammer which is lifted by mechanical means and known as a drop-hammer, are called *drop-forgings.* The shape of the forging is cut out or " sunk " into dies, so that often a single blow of the hammer on the dies shapes the heated iron bar to the desired form. A drop-forging can be produced with a tolerance of $\frac{1}{32}$ inch as an ordinary commercial limit for small work, although it is possible, by careful forging and supplemental restriking, and providing the forging is fairly small, to produce work within a few thousandths of an inch. The degree of accuracy possible in drop forging is, however, very seldom realized, and for work within very fine limits it is necessary to have multiple dies; that is, one or more pairs of dies for roughing-out, and one or more pairs of dies for the finishing operations. *String forging* is the most economical way of drop-forging certain small pieces. By string forging is meant the forming of small pieces in a string, without cutting off each piece separately after forging.

Fin and Flash. — Excess stock that is squeezed out of the impression into the narrow space between the upper and lower sections of a drop-forging die, is called the " fin." To take care of this metal that is crowded out of the impression, each die is relieved around the impression by milling a flat, shallow recess, about $\frac{1}{64}$ inch deep and $\frac{5}{8}$ inch in width all around the impression. These dimensions are for dies of average size; in larger dies, the recess or " flash," as it is called, would be a little deeper and wider. Both the upper and the lower dies are flashed in this manner. In addition, the upper die is back-flashed; that is, there is a deeper recess, sometimes called the " gutter," milled around the impression at a distance of $\frac{1}{4}$ inch from the impression at every point. This back-flash is $\frac{3}{64}$ inch deep, and acts as a relief for the excess metal after it has squeezed through the flash proper. Only the finishing impression is provided with flash and back-flash. The fin is trimmed from the forging by means of trimming dies, when the forging is either hot or cold, depending upon the size and shape.

DROP-FORGING DIE MATERIALS. The material from which drop-forging dies are made is usually either a high-grade open-hearth carbon

steel or an alloy steel containing certain percentages of nickel and chromium, although other alloys are used in special cases. When drop-forging dies are made from open-hearth steel a 0.60 per cent carbon steel is generally used. In some cases, however, steel as low as 0.40 per cent carbon and as high as 0.85 per cent carbon is used, but few shops use anything but 0.60 per cent carbon steel for the general run of work. If a low-carbon steel is used, a special hardening treatment is required, which outweighs any saving in the price of the steel. The high-carbon steels make good dies, but except in special cases, there is no necessity for using so high-priced a steel. The average 0.60 per cent carbon steel die, if properly hardened, should last for from 15,000 to 40,000 forgings, and sometimes as many as 70,000 forgings are made from one set of dies. In making dies for large forgings, it is often considered advisable to use 0.80 per cent carbon steel for the dies, and not to harden them. This obviates the danger of "checking" or cracking in hardening, and the steel, unhardened, is hard enough to resist the tendency to stretch.

Special *chrome-nickel steel* has been found particularly suitable for producing drop-forgings from a high grade of material. The development in the use of chrome-nickel steel has been due largely to the demands of the automobile industry, in which there are used a great variety of intricately shaped drop-forged parts made from dense fine-grained alloy steels of various compositions.

Cast-steel dies are sometimes used, but the castings must be sound and free from blow-holes. The advantage of casting the die impressions over sinking them is in the saving of time in manufacture, and more especially in the possibility of producing more intricate shapes. Cast-steel die-blocks are not recommended, however, unless the design of the forging demands that the impressions be cast. On the lighter classes of drop-forgings, particularly if there are only a few to be made from one impression, *cast-iron die-blocks* have been used with fair success. The finest grain of cast iron should be used in making drop-forging dies, and the structure of the iron should be homogeneous.

DROP-FORGING DIE-SINKING MACHINES. See Die-sinking.

DROP-FORGING DIES, LEAD PROOF. In making drop-forging dies, it is customary to take a so-called "lead proof" from the impressions in the upper and lower dies, in order to make sure that the forging will have the right appearance when it comes from the dies, and to ascertain that there are no defective places in the impression. In making a lead proof, the impressions of both the upper and lower dies are cleaned and dusted with powdered chalk, the dies placed on end and clamped together with large C-clamps, and the heated lead slowly and evenly poured into the

dies until it fills the impression and gate. As soon as the lead has cooled, the dies are unclamped and the lead proof removed and examined. The lead proof will show any places on the forging that are not perfect, and, by weighing the lead, it is possible to ascertain the weight of the finished forging. Roughly speaking, two-thirds the weight of the lead proof will equal the weight of the finished forging. The shrinkage of lead is practically the same as that of steel, so that the finished forging will have practically the same dimensions as the lead proof.

DROP-FORGING STEEL. Generally speaking, low-carbon steels are more suitable for drop forging than high-carbon steels, because the latter are more difficult to work, there being a tendency to burn the steel on account of the high temperature to which it must be heated for forging. Nickel steels containing up to 3.5 per cent of nickel with about 0.30 per cent of carbon can be drop-forged with comparative ease. Nickel-chromium steels are difficult to drop-forge, particularly when the chromium content is over 1.3 per cent and the nickel content over 2 per cent, with the carbon content about 0.35 per cent; but these steels are very hard when heat-treated and have a very high tensile strength and elastic limit.

The great value of chrome-vanadium steels for drop forging lies in the fact that they can be very easily forged as compared with nickel-chromium steels. A suitable composition would be 1.2 per cent of chromium, 0.16 per cent of vanadium, and 0.32 per cent of carbon. This steel resists bending, torsional, impact, and vibrating stresses to a remarkable degree. Even the best steel may be ruined in drop forging in any one of three principal ways: 1. By careless treatment, in not carrying out the steel maker's instructions. 2. By incorrect treatment, due to ignorance of the properties of the steel used. 3. By working the steel at a temperature unsuitable for that particular brand of steel.

DROP-HAMMERS. Drop-hammers are so named because the hammer head is lifted by a power and then dropped upon the work. Hammers of this type are extensively used for producing drop-forgings, and are made in two general types, known as *board* drop-hammers and *steam* drop-hammers. With the former type, the hammer head, in its descent, is acted upon by gravity alone, whereas, in the case of a steam drop-hammer, the force of the hammer blow is greatly increased by the action of steam, which is admitted to the upper side of the hammer piston. In addition to the board and steam drop-hammers, there are what are known as "drop presses" or "drops," which are used for stamping and bending operations in connection with the manufacture of jewelry, silverware, etc. The crank-operated drop-hammer or "Peck lift" was largely used for drop forging in the early days of the industry, but this type is now confined principally to stamping work and the silverware trade.

The first patent containing the basic principle of the *board drop-hammer* was taken out by Goulding & Cheney in 1861, the patent covering a drop-hammer that was lifted by means of a belt or board placed between rolls running in opposite directions. In the operation of a board drop-hammer, the hammer proper is raised by the action of friction rolls which bear against a board that is attached to the hammer. The action of the hammer is controlled by a foot-treadle which is connected with board clamps. There are two of these clamps, one located at the front and the other at the rear of the board, which serve to hold the hammer in its upper position when the foot-treadle is released. When the foot-treadle is depressed, these board clamps are withdrawn, thus releasing the board and allowing the hammer to drop. By a greater or less depression of the treadle, variation in the force of the blow may be obtained regardless of the stroke or fall for which the hammer is adjusted. For instance, when the foot-treadle is pushed all the way down, the clamps are entirely released and the hammer drops freely, whereas, if the treadle is only partly depressed, there is more or less friction between the board and the clamps, and the fall of the hammer is retarded a corresponding amount. See also Steam Drop-hammers.

DROP PRESSES. The type of drop-hammer commonly known as a *drop press* has a base or anvil and two guides or uprights the same as a board drop-hammer, but the hammer proper is lifted by a different type of mechanism. A typical design of drop press is arranged as follows: The "lifter" or mechanism for raising the hammer is a separate unit. The hammer is connected to the lifter by a belt, the upper end of which is attached to a crank. This crank is driven by means of a pawl-and-ratchet mechanism which serves to elevate the hammer and then allows it to drop suddenly. The shaft carrying the ratchet is driven, through suitable gearing, from a shaft at the rear on which belt pulleys are mounted.

One of the advantages claimed for the lifting mechanism operating on the crank principle is that the hammer is started slowly from rest and the elevating speed is gradually increased, which relieves the mechanism from sudden strains, so that it is very durable. The lifter is designed to give a quick, snappy blow, although some of the older types were inferior in this respect. The mechanism is operated in practically the same way as a blanking or punching press, it being tripped by operating a foot-treadle. The height to which the hammer is raised and the force of the blow is regulated by changing the radial position of a crank-pin, which is clamped to a toothed arm that provides fine adjustment and at the same time a firm grip.

Drop presses are extensively used in the manufacture of sheet-metal goods, hardware, cutlery, silverware, jewelry, etc., for bending, forming, and stamping operations. Special designs are also made for stamping

or embossing and paneling large sheets of thin metal, such as are used by metallic cornice and ceiling manufacturers.

DRUM CAM. A cam consisting of a cylindrical barrel into the cylindrical surface of which a groove is cut for the cam roller. Instead of a groove, the cam surface may be constructed by attaching guiding pieces on the surface of a cylindrical drum.

DRUM CONTROLLER. This is a hand-operated electric motor controller of the non-automatic type consisting of a revolving drum carrying segments so arranged as to make contact in a predetermined order with contact fingers. Drum controllers are compact, mechanically strong and simple to operate, and can easily be mounted on the motor-driven machinery which they are to control, with the controller handle placed in a position most convenient to the operator. This type of controller is frequently used for machine tools, printing presses, and cranes. See also Commutator Controller.

DRUM-WOUND ARMATURE. A drum-wound armature for a generator or motor is one which consists of a core on which the conductors are so wound that the coils are entirely on the surface of the core, and so spaced as to be under poles of opposite polarity at the same time.

"DRUNKEN" THREAD. A "drunken" thread, according to prevalent usage of this expression by machinists, etc., is a thread that does not coincide with a true helix or advance uniformly. This irregularity in a taper thread may be due to the fact that in taper turning with the tailstock set over, the work does not turn with a uniform angular velocity, while the cutting tool is advancing along the work longitudinally with a uniform linear velocity. The change in the pitch and the irregularity of the thread is so small as to be imperceptible to the eye, if the taper is slight, but as the tapers increase to, say, $\frac{3}{4}$ inch per foot or more, the errors become more pronounced. To avoid this defect, a taper attachment should be used for taper thread cutting.

DRY-AIR PUMP. Dry-air pumps are used for condenser service and are connected with the condensing chamber in such a manner as to withdraw the air only, and not the water of condensation which is removed by a separate *hot-well pump*. This arrangement makes it possible to use valves designed especially for air and thus maintain a considerably higher vacuum. Pumps of this type have come into use with the advent of the steam turbine, where a high vacuum is required.

DRY ANALYSIS. A chemical analysis performed with dry reagents and the assistance of heat.

DRY CELLS. The wet cell type of battery has been replaced largely by the "dry cell" which is more convenient, portable, requires less space, and is cheaper. The dry cell is usually made by placing a carbon cathode and depolarizing compound inside of a zinc cylinder, which forms the anode. The cathode and depolarizer are separated from the zinc by some absorbent material which is saturated with the electrolyte, usually a solution of sal-ammoniac and zinc chloride; but sometimes the separation is made by mixing the electrolyte with some gelatinous body, which is poured into place while hot and, on cooling, forms a jelly. The top of the cell is then sealed to prevent evaporation. Most cells are 6 inches high.

DRY COLORING. The term "dry coloring" relates to a method of coloring metals by the use of compounds which are mixed together, forming pastes that are applied with a brush. This paste is allowed to remain a number of hours and is then rubbed off. However, the *wet method*, that is, the process of dipping into a chemical solution, presents many advantages, both as regards economy of time and uniform results.

DRYERS, CENTRIFUGAL. Centrifugal dryers are used for drying metal articles in connection with plating, japanning, etc., and also for cleaning the products from screw machines or other automatic machines. A centrifugal dryer consists of a perforated pan or basket which holds the work and is revolved usually from 1000 to 1500 revolutions per minute, while heated air is circulated through the parts being dried. One type of dryer has a steam coil for heating the air which is forced through the contents of the basket by a fan or blower. Another type contains an electrically-heated grid for supplying the heated air. The drying pan or basket may be revolved either by belt or a direct-connected motor. The drying operation may require from 2 or 3 minutes up to, say, 5 to 7 minutes, depending upon the nature and shape of the product.

DRY MEASURE. One bushel (U. S. or Winchester struck bushel) = 1.2445 cubic foot = 2150.42 cubic inches; 1 bushel = 4 pecks = 32 quarts = 64 pints; 1 peck = 8 quarts = 16 pints; 1 quart = 2 pints; 1 heaped bushel = $1\frac{1}{4}$ struck bushel; 1 cubic foot = 0.8036 struck bushel; 1 British Imperial bushel = 8 Imperial gallons = 1.2837 cubic foot = 2218.19 cubic inches.

DRY PROCESS. In assaying, "dry process" is a method for ascertaining the quantity of metals in ores. The process consists mainly in oxidizing the ores by the agency of heat. It is also known as the pyrometallurgical process.

DRY SAND CORE. This is a part of a foundry mold, inserted in the mold cavity in such a way as to form either a hole or a recess in the casting.

It is made from coarse sand, free from clay, the sand being mixed with a bond or binder until it is of about the consistency of heavy flour dough, and then baked in a core oven until it is dry and hard.

DUCTILITY OF METALS. The ductility of metals refers to their susceptibility of being drawn into wire. The finer the wire that can be drawn from a given metal, the more ductile it is. Of the metals, platinum is one of the most ductile. Next in order, of the more common metals, come silver, iron, copper, gold, aluminum, zinc, tin, and lead. The ductility is closely related to the property of metals known as "elongation."

DURALOY. Duraloy is a trade name applied to chrome iron alloys containing a larger percentage of chromium than ordinary stainless steel, the chromium content ranging from 27 to 30 per cent. This alloy was developed originally for high temperature installations as it resists oxidation at temperatures up to about 2100 degrees F. Duraloy has unusual resistance to most corroding elements and particularly to nitric acid, most of the organic acids and to the acid water found in the coal fields. Castings containing 16 to 18 per cent chromium resist corrosion practically the same as those of high chromium content, but are not satisfactory for high-temperature installations. This alloy is used in the form of castings, forgings, bars, sheets, plates, wire, and fabricated forms. The carbon content depends upon the application and also upon the form of the material. For example, the carbon in rolled products is kept low to insure ductility, and in castings it is varied to give either satisfactory machining qualities or extreme hardness and resistance to abrasion. The strength of Duraloy varies with the analysis, treatment, and form, but in general the ultimate tensile strength in pounds per square inch varies from 40,000 to 50,000 for cast products, and from 80,000 to 90,000 for rolled material. The strength at high temperatures can only be determined accurately by tests extending over long periods, because fatigue is a very important factor; however, Duraloy has a tensile strength at least of 3500 pounds per square inch when subjected over a long period to 1650 degrees F.

DURALUMIN. Duralumin is an aluminum alloy which is somewhat heavier than pure aluminum but has practically the strength of steel; hence, this is an alloy of great value where lightness combined with strength are required, as, for example, in the framework construction of aircraft. Duralumin was first made in Germany and developed by A. Wilm and associates, during the years intervening between 1903–1914. Duralumin is non-magnetic, withstands atmospheric influences, and offers unusual resistance to sea and fresh waters. It is only slightly affected by numerous chemicals which readily corrode other metals and alloys and does not tarnish in the presence of sulphurated hydrogen. It takes a polish equal

to that of nickel-plated articles and remains bright without cleaning longer than plated or silvered articles. It is an ideal substitute for aluminum, German silver, brass, copper, and steel when lightness combined with strength is required. Although duralumin is only one-third the weight of steel, heat-treated duralumin forgings approximate mild steel forgings in strength, so that wherever weight is a deciding factor, duralumin is satisfactory for most shapes made by hot-working or forging. Duralumin forgings are especially desirable for reciprocating or moving parts where the inertia due to their own weight, forms a large part of the total stress. Duralumin machines easily and, as it does not corrode, is suitable for use in many places where weight is not the prime essential.

Experiments have been made to determine the electrolytic effect from junctions of duralumin with iron or steel. These were made by riveting duralumin bars to iron plates and then placing them in artificial sea-water. The result was only a slight destruction of the iron and a reduction in the weight of the bars of about 0.23 per cent, so there is no objection to using duralumin and iron junctions in aircraft.

DURALUMIN COMPOSITION AND STRENGTH. The chemical composition of duralumin varies within the following limits: copper 3 to 5 per cent, magnesium 0.3 to 0.6 per cent, manganese 0.4 to 1 per cent, the remainder being aluminum plus impurities. Small quantities of other metals are sometimes added for certain reasons; for instance, chromium may be added to increase the burnishing qualities of the metal. The strength and toughness of duralumin are comparable with mild steel, and are obtained with a specific gravity of about 2.8 as against 7.8 for steel. The melting point is approximately 1210 degrees F., the recalescence point, 970 degrees F., the annealing temperature approximately 680 degrees F., and the coefficient of expansion 0.00001798 per F. degree of temperature. In the annealed form duralumin can be drawn, spun, stamped, and formed into a great variety of shapes, similar to brass and mild steel. The physical properties in this state average: Ultimate tensile strength, 25,000 to 35,000 pounds per square inch; yield point, 22,000 to 24,000 pounds per square inch; elongation in 2 inches, 12 to 15 per cent; Brinell hardness, 57; and scleroscope hardness, 11.

Duralumin in its heat-treated form may be slightly shaped or formed and may be bent cold to 180 degrees over a mandrel having a diameter of four times the thickness of the sheet. Its remarkable tensile strength is here combined with its maximum elongation as follows: Ultimate tensile strength, 55,000 to 62,000 pounds per square inch; yield point, 30,000 to 36,000 pounds per square inch; elongation in 2 inches, 18 to 25 per cent; Brinell hardness, 93 to 100; and scleroscope hardness, 23 to 27. Heat-treated duralumin forgings have similar physical properties. When the

sections of forgings are heavy, it is advisable to lower the minimum tensile requirements to 50,000 pounds per square inch. This will cause a proportional increase in elongation. Heat-treated and hard-rolled duralumin is used where no bending or forming is required. It is a hard, strong, springy metal in this state, and machines and polishes well. Its physical properties in this form average: Ultimate tensile strength, 67,000 to 72,000 pounds per square inch; yield point, 58,000 to 65,000 pounds per square inch; elongation in 2 inches, 3 to 8 per cent; Brinell hardness, 130 to 140; and scleroscope hardness, 39 to 42.

Influence of Heat and Cold. — Heat has an important influence on the strength of duralumin, the results of tests indicating that the strength decreases 10 per cent for an increase in temperature of 212 degrees F. and about 20 per cent for an increase of 302 degrees F. The loss in strength increases with the increase of temperature. On first heating the increase in elongation is hardly appreciable, and between 302 and 392 degrees F., it decreases. At 482 degrees F., the elongation becomes the same as at the room temperature. Upon further heating the elongation increases with a rising temperature; consequently, wherever duralumin is exposed to heat, the possible decrease of strength must always be considered. Opposed to this, the influence of cooling on the strength properties is less unfavorable. The strength and elongation increase somewhat with a decrease in temperature.

DURALUMIN DROP-FORGING. Duralumin may be drop-forged in the same dies used for steel. Although the coefficient of expansion of aluminum is twice that of steel, the forging temperature is only one-half, so that dies with a shrinkage allowance for steel are suitable for duralumin. Best results are obtained by modifying the design of the drop-forging to suit duralumin, bearing in mind that duralumin does not flow quite so readily as steel. Owing to the sluggish flow, the dies must also be very smooth. The correct forging temperature is about 900 degrees F. If heated above 930 degrees F., duralumin becomes crumbly, and when drop-forged is likely to disintegrate. The correct forging temperature range, therefore, is important, but may vary from 880 to 920 degrees F.

DURALUMIN GEARS. For a given section, the weight of duralumin is about one-third that of bronze, and for parts produced in large quantities, duralumin is the cheaper of the two metals. Therefore duralumin is an ideal material for worm-wheels, and especially those used in automobile constructions, provided the wearing qualities are satisfactory. The tensile strength and relatively high elastic limit insure a superior tooth strength, while the homogeneous structure and uniform hardness of heat-treated duralumin forgings insure entire freedom from hard spots, porosity

and spongy areas so common in bronze castings, which entail not only a machine loss but uneven tooth wear in service. The data from various laboratory tests on bronze and duralumin worm-wheels may be summarized by saying that tests destructive to duralumin worm-wheels were also destructive to those made of bronze.

An important condition was revealed in tests with worm-wheels made of duralumin, by examining the lubricant used. After long tests with bronze wheels where the oil has not been changed, the oil is found to contain particles of bronze in suspension. This condition is sometimes very marked and is of importance not only as indicating tooth wear but as showing the deterioration of the lubricating value of the oil. Oil heavily charged with metallic particles acts more like an abrasive and less like a lubricant, and therefore is an important factor in the wear of automobile gearing, where the oil is infrequently renewed. When duralumin wheels were used, the charging of the oil with metallic particles was practically negligible.

The different tests point to excellent life for duralumin worm-wheels, unless the wheels are roughened by lack of lubrication or too high a tooth pressure which will injure or destroy any worm-gearing. The same qualities that make duralumin a desirable material for worm-wheels also make this material valuable for other types of gears. It is suitable for this class of work when the pressures are sufficiently within its elastic limit of 30,000 pounds. Where this condition is met, and weight and quietness are desirable, duralumin will satisfactorily replace iron, steel, brass, fiber, fabrics, etc. Where duralumin can be run with steel rather than against itself the best results are obtained. An example of this application is found in the timing gear trains of automobile motors where both long life and quietness are essential. Helical duralumin gears alternated with steel gears have been very successful in service. That duralumin gears when meshed with steel gears are quiet may seem somewhat contradictory since, when struck, all duralumin forgings are resonant; however, quiet operation is obtained and is undoubtedly due to the difference in pitch of the sound vibrations of steel and duralumin.

When duralumin and hardened steel are run together the results are always good. An example of this application was shown by having duralumin connecting-rods running direct on the wrist-pins. A better life was obtained at this point than with bronze-bushed rods of equal bearing area. Comparative tests of bearings made from duralumin and bearings made from babbitt show that for shaft speeds exceeding 700 revolutions per minute and loads over 200 pounds per square inch, duralumin bearings developed less friction, remained cooler and showed practically no loss in weight under most severe conditions. For lower bearing pressure and slower speeds, babbitt metal was superior.

DURALUMIN HEAT-TREATMENT. An unusual feature of duralumin is that after it has been hot-, or hot- and cold-worked, it may be further strengthened and toughened from 40 to 50 per cent by heat-treatment. This heat-treatment is somewhat analogous to the heat-treating of alloy steels and consists of quenching at temperatures below the melting point, followed by an aging process. The increased physical properties are not all produced immediately on quenching, but increase during the subsequent aging.

The final rolling or forging of duralumin may be done hot or cold, according to the character of the work being handled or the shape it is desired to produce. The hot- or cold-worked metal in its final shape shows greatly improved physical properties over the cast ingot, but the full development of its qualities is obtained only by a specific heat-treatment. To obtain this heat-treatment, the metal is heated to a temperature of from 930 to 970 degrees F. for a period of time depending upon the section of the piece, and then immediately quenched. The heating and quenching improve the physical qualities of the metal, but the maximum results are obtained only by a subsequent aging. During the aging period, which takes from one to five days, the tensile strength, hardness, and elongation of the alloy increase considerably. Aging is sometimes accelerated by placing the metal in a hot water bath of a temperature up to 212 degrees F. or in a hot room. The heat-treatment develops properties which have not been obtained in a like degree in any other aluminum alloy. The cast ingot has a tensile strength of from 28,000 to 32,000 pounds per square inch, and an elongation of from 1 to 3 per cent.

When duralumin in its finished state must be subjected to several drawing, forming, or similar operations, it is often found necessary to anneal the sheets between operations in precisely the same manner as with other metals. This annealing should be done at about 660 degrees F. If several drawing operations are to be performed, it may be necessary to anneal the metal between such operations. Annealed duralumin can be heat-treated and the maximum physical properties obtained, no matter what shape or form the metal may be reduced to; conversely, heat-treated duralumin may be annealed. Duralumin may be cold-worked after heat-treatment and aging. This operation produces a hard smooth finish, and materially increases the tensile strength of the metal at the expense of elongation.

Heat-treatment Experiments. — In order to ascertain the relation between the heat-treatment of duralumin and its mechanical properties, the Bureau of Standards made a series of experiments resulting in the following conclusions: When duralumin is rapidly cooled by quenching from temperatures between 250 and 520° C. (482 and 968° F.), and aged thereupon at temperatures from 0 to 200° C. (0 to 392° F.), the hardness and, at least

at lower aging temperatures, the ductility increase. The actual values of hardness and ductility thus obtained depend upon the quenching temperature; they increase with that temperature up to about 520° C. (968° F.). In order to develop the best mechanical properties by heat treatment, a quenching temperature should be used as near this as is possible without running risk of burning the metal. In practice it should be possible to quench from temperatures between 510 and 515° C. (950 and 959° F.).

The period of time at which sheet material should profitably be held at the quenching temperature lies between 10 and 20 minutes. Heavier sections such as bars might require more time at this temperature, as the structure of such sections would be coarser. Quenching is best and most conveniently carried out in boiling water. The mechanical properties are better after quenching in hot than after quenching in cold water, and there is less danger of cracking due to cooling stresses.

The best temperature for subsequent aging depends upon the mechanical properties that are desired. For most purposes it will be found best to age at 100° C. (212° F.) for about 5 to 6 days. The greater portion of the hardening effect takes place within this period. Such a treatment develops both high strength and high ductility. If a material having a higher proportional limit but lower ductility is desired, the material may be aged at higher temperatures up to 150° C. (302° F.) for from 2 to 4 days.

DURALUMIN MANUFACTURE. The manufacture of duralumin is somewhat analogous to that of steel and is carried on in the following sequence: Manufacture of the alloy from its aluminum base; casting the ingot; hot-rolling or cogging in blooms, billets, or slabs; hot- or cold-working to the final shape; heat-treating.

The ingots are poured at as low a temperature as practicable, that is, just enough above the melting point to fill the mold and prevent cold shuts. They are then either hot-rolled or cogged into slabs, blooms or billets, similar to the manner of working steel. This hot working is done at a temperature of from 840 to 900 degrees F. Such low temperatures cannot be judged by color, and it is therefore necessary to use pyrometers in heating the metal previous to working it.

DURIRON. Duriron is a hard, white iron silicide, highly resistant to practically all commercial acids. The composition is approximately as follows: Silicon, 14.25 to 14.50; Carbon, 0.60 to 0.80; Manganese, 0.30 to 0.35; Sulphur, under .05; Phosphorous, under .15.

The hardness of duriron is such that it cannot be machined by a cutting tool and must be finished by grinding. Duriron can be used safely in connection with nitric, sulphuric, acetic, and a large list of other commercial acids at practically any concentration or temperature. This is also

practically true of cold hydrochloric acid. With hot hydrochloric acid, however, more consideration must be given to the conditions.

DUTCH METAL. An alloy of copper and zinc resembling gold. It contains about 80 per cent of copper and 20 per cent of zinc.

DUTCH OVEN FURNACE. The Dutch oven type of boiler furnace is especially adapted for the burning of bituminous coal. The furnace proper is extended in front of the boiler, and at the rear of this is a mixing wall or baffle which gives a hot wall for the burning gases to strike against as they rise from the bed of fuel. This gives the hydro-carbons ample opportunity, after being distilled from the fresh fuel on the grate, to become thoroughly mixed with the air before passing into the combustion chamber at the rear of the wall.

DUTY OF STEAM PUMP. See Pump Duty.

DYNAMIC BALANCE. If the journals or bearings of a cylindrical part, such as a drum or rotor, were mounted on level straightedges, any lack of balance would be indicated by a turning movement, the heavy side finally being located at the bottom. This lack of balance might be corrected either by adding weights or by removing metal, so that the cylindrical body would stand in any position. It would then be in *static* or *standing balance*, but it might not be in balance if rotated at high speed, especially if the corrections for lack of balance were not made in planes (perpendicular to the axis) in which the unbalanced masses are located. When the unbalanced portions are located in an axial, as well as in a circumferential direction, and corrections made accordingly, then the body will not only be in static, but in running or dynamic balance as well. See Balancing Methods.

DYNAMIC BRAKE. This is an electric brake used for slowing down and stopping motors driving industrial machinery, especially hoists and cranes. The motor acts as a generator, the generating action causing the motor shaft to absorb mechanical energy from the machine to which it is connected and thereby establish a braking action. Dynamic brakes are generally supplemented by mechanical friction brakes, because the dynamic braking action ceases when the motor comes to rest.

"Dynamic braking" is the term used when power is absorbed in a rheostat, to distinguish it from "regenerative braking" which indicates that the power is returned to the constant voltage power system. The main difference between the two forms, so far as the control of an electric motor is concerned, is that, by means of dynamic braking, a much wider range of speed operation can be obtained — about from 10 to 150 per cent of full speed — whereas with regenerative braking nothing less than full

speed can be obtained. A combination of dynamic braking and regenerative braking is used on crane hoists, elevators, reversing planers, etc. Sometimes regenerative braking alone is used on long hoists where the time of lowering is something like one-half of a minute or more. See Regenerative Braking.

DYNAMIC CONTROL. The dynamic control is used with polyphase induction motors with wound rotor, the secondary resistance being replaced by a dynamic regulating set. With the ordinary rheostat control the secondary energy is dissipated as heat and thus wasted, whereas with the dynamic regulation the major portion of this energy is returned to the system. There are two kinds of regulating sets in use. One consists of a polyphase commutator motor connected to the slip rings of the main induction motor, thus receiving the slip energy that would usually be dissipated in a rheostat. This energy is then returned to the power system through an induction or synchronous generator driven by the polyphase commutator motor. The second system is, in principle, identical to the one just described. It differs only in the method of returning the slip energy of the main motor, in that this energy is converted to direct-current power by a rotary converter connected to the slip rings of the main motor, and either returned to the supply system through a motor-generator or delivered to a direct-current motor mounted on the main motor shaft. This system, therefore, requires one more machine than the former.

DYNAMIC ELECTRICITY. The term *dynamic electricity* relates to electricity which flows through some kind of a conductor as a current; for example, when the terminals of one or more electrical batteries are connected by means of a wire, a current will flow through the wire from one terminal to another.

DYNAMIC PRESSURE. The pressure exerted by a fluid or gas, flowing in a duct or pipe, due to the momentum of the moving fluid in the direction of the flow.

DYNAMITE. Dynamite is nitroglycerine to which an absorbent has been added in sufficient quantity to form a solid mass, such as diatomaceous earth, clay, ashes, or carbon. It is important that the adulterant have the correct absorbing qualities, for an excess of nitro will naturally exude, while if the absorbent is in excess, it is likely to crumble. Either condition is likely to give serious trouble at some unexpected moment. Both nitroglycerine and dynamite are particularly dangerous, owing to their instability.

DYNAMO. The name dynamo is an abbreviation of the longer original name, "dynamo-electric machine," and it is a machine for converting mechanical into electrical energy. The name "dynamo" is not used in

the electrical industries today to the extent that it was used in the earlier days of the development of electrical machinery, the name *generator* having, in the United States at least, almost entirely replaced *dynamo*.

DYNAMO INVENTION. The first dynamo-electric machine which utilized current from the armature, in the coils of the field magnets, was invented by Hjorth of Copenhagen, and was patented in England in 1855. Although the principle of the dynamo was embodied in this patent, the practical value of such a machine was not appreciated until some time later, and the development of the highly efficient machine now in use has been due to the work of a number of different inventors. Patents for the polyphase or multiphase current were granted to Tesla in 1888.

DYNAMOMETERS. A dynamometer is an apparatus for measuring the power developed, absorbed, or transmitted by any piece of machinery. Dynamometers are of three classes. Those of the first class are known as *absorption dynamometers*, and absorb the power generated or transmitted by any mechanism, measuring it during the process of absorption. Dynamometers of the second class measure the power by transmitting it through the mechanism of the dynamometer from the apparatus in which it is generated, or to the apparatus in which it is to be utilized. Dynamometers of this class are known as *transmission dynamometers*. Dynamometers of the third class operate by simultaneously measuring the pressure and volume of a confined fluid, and are known as *indicators*. Indicators are very seldom used, however, except for the measurement of the power generated by steam or gas engines or absorbed by refrigerating machinery, air compressors, or pumps.

DYNAMOMETERS OF ELECTRICAL TYPE. An electrical dynamometer is an apparatus for measuring the power of an electric current, based on the mutual action of currents flowing in two coils. It consists principally of one fixed and one movable coil, which, in the normal position, are at right angles to each other. Both coils are connected in series, and, when a current traverses the coils, the fields produced are at right angles; hence, the coils tend to take up a parallel position. The movable coil with an attached pointer will be deflected, the deflection measuring directly the electric current.

DYNAMO OIL. This is a viscous neutral oil having a flash point of 400 to 425 degrees F., a fire test from 450 to 500 degrees F., a specific gravity of 30 to 32 degrees Baumé, a coal test of from 15 to 30 degrees F., and a Saybolt viscosity of from 140 to 225.

DYNAMOTOR. A dynamotor is a direct-current machine which combines both motor and generator action in one magnetic field; it is used

for transforming high-voltage direct current into low-voltage direct current, or *vice versa;* hence, it performs the same functions with relation to direct current as a transformer does in relation to alternating current. These machines are used mainly for obtaining large currents for starting other motors, or for giving low voltages or a fractional voltage in a multi-voltage system, for speed control. They are also employed for obtaining a low voltage for telephone and telegraph systems, and for obtaining the low voltage and large currents required for electrolytic work. The dynamotor has an armature with two separate windings and two separate commutators. Either winding may be used as a motor winding and the other as a generator winding. A dynamotor is smaller, lighter, and cheaper than a motor-generator set, although the latter has the advantages that the high- and low-voltage circuits are absolutely independent, and that there is no fixed relation between the two voltage values.

DYNE. One dyne is the unit of force in the C. G. S. (centimeter-gram-second) system, frequently also known as the *absolute system of measurement.* One dyne is equivalent to $\frac{1}{981}$ gram, this value being derived from the fact that the acceleration due to gravity (at Paris) equals 981 centimeters in one second.

EARTH CIRCUIT. In electricity, an earth circuit is one in which the earth or ground forms the path for the current. Often a metallic circuit is grounded, as, for example, the return circuit for direct-current railways, where the track rails form the grounded return circuit. The negative terminal of the generator should always be connected to the grounded circuit, so as to minimize electrolysis.

EARTH LOAD CAPACITY. See under Foundations for Machinery.

EARTH OR SOIL WEIGHT. Loose earth has a weight of approximately 75 pounds per cubic foot and rammed earth, 100 pounds per cubic foot. The solid crust of the earth, according to an estimate, is composed approximately of the following elements: Oxygen, 44.0 to 48.7 per cent; silicon, 22.8 to 36.2 per cent; aluminum, 6.1 to 9.9 per cent; iron, 2.4 to 9.9 per cent; calcium, 0.9 to 6.6 per cent; magnesium, 0.1 to 2.7 per cent; sodium, 2.4 to 2.5 per cent; potassium, 1.7 to 3.1 per cent.

ECCENTRIC. An eccentric is, in reality, a short crank with a crankpin of such size that it surrounds the shaft. The slide valve of many steam engines is driven by an eccentric attached to the main shaft. The *throw* of an eccentric is equal to the diameter of a circle described by the center of the eccentric as it rotates with the shaft. The travel of the valve equals the throw of the eccentric, unless there is an intervening rocker with lever arms of unequal length, which causes a variation in the movement of the valve. The radius of an eccentric, or the distance from the center of its shaft hole to the center of the eccentric, is sometimes referred to as the *eccentricity*. This radius is sometimes called the throw, although that is generally considered to be an incorrect definition.

ECCENTRIC GEARS. In some of the developments in automobile accessories, such as self-starters and speedometers, conditions exist which require a high velocity ratio in a comparatively small space; this requirement has led to the development of what are commonly known as *eccentric gear combinations*. These combinations are, in reality, planetary gearing consisting either of two gears or of four or more gears.

ECHOLS THREAD. Chip room is of great importance in machine taps and tapper taps where the cutting speed is high and always in one direction. The tap as well as the nut to be threaded is liable to be injured, if ample space for the chips to pass away from the cutting edges is not provided. A method of decreasing the number of cutting edges, as well as increasing the amount of chip room, is embodied in the "Echols thread," where every alternate tooth is removed. If a tap has an even number of flutes, the removal of every other tooth in the lands will be equivalent to the removal of the teeth of a continuous thread. It is, therefore, necessary

that taps provided with this thread be made with an odd number of lands, so that removing the tooth in alternate lands may result in removing every other tooth in each individual land. Machine taps are often provided with the Echols thread.

ECONOMIZER. An apparatus designed to save waste flue-gas heat in power plants is called an *economizer* and consists of a bank of tubes through which the water passes on its way to the boiler. The economizer is usually placed behind a row of boilers and a little above them. Although this heat is commonly used in warming the feed water, the term *feed-water heater* is only applied to devices employing either live or exhaust steam.

EDDY-CURRENTS. Eddy-currents, sometimes also called " Foucault " currents, are irregular electric currents induced in an iron core or other metallic mass along closed paths of least resistance linked with the flux, when the magnetic flux varies in the core. These currents permeate the whole bulk of the core; they may be considerably minimized by laminating the core.

EDGING AXES. The operation of grinding off the " flash " left on axe forgings is called " edging." The old method of edging axes was by means of sandstone wheels. The forgings were held under pressure against the revolving sandstone, the pressure being exerted by a steel lever bar whose fulcrum was in an adjustable platform in front of the wheel. The old method is still in use but artificial wheels, which have replaced sandstone wheels for other axe grinding operations, are now used in many shops for the edging operation.

EDISON BATTERY. This is an alkaline storage battery in which the active material of the positive plate is nickel hydrate, the active material of the negative plate is black oxide of iron, and the electrolyte is a solution of potash in water.

EDISON-LALANDE CELL. This is a primary cell or battery in which the anode is amalgamated zinc in the form of two sheets hung at each side of the cathode. The depolarizer consists of cupric oxide in the form of a plate, the surface of which is reduced to metallic copper to form the cathode. The electrolyte is a solution of potassium nitrate. The cell is used for closed circuits and large currents. The electromotive force is low — about 0.7 volt — but as the internal resistance is also low, the currents are large. The cell may be left unused for several months without evaporation, the electrolyte being covered with a layer of heavy mineral oil for this purpose.

EDISON WIRE GAGE. The Edison wire gage is simply another name given to the circular mil gage system for measuring electric wires. The gage numbers correspond to the numbers of thousands of circular mils of

area of cross-section of the wire; hence, a wire, the cross-section of which is 110,000 circular mils, is gage No. 110. The American or Brown & Sharpe wire gage is generally used for electrical wires, and may be considered the standard for this purpose.

EFFECTIVE PRESSURE. The effective pressure in the cylinder of a steam engine varies throughout the stroke. The mean effective pressure (M.E.P.) is the average of all the effective pressures, and this average multiplied by the length of stroke gives the work done per stroke. The mean effective pressure may be determined from an indicator card, and it is used in calculating the *indicated horsepower* of an engine.

EFFECTIVE PULL. The effective pull of a belt is the difference in tension between the tight and slack sides of the belt. The approximate horsepower that may be transmitted by a belt can be determined by multiplying the effective pull in pounds per inch of belt width, by the width of the belt in inches and the speed of the belt in feet per minute, and dividing the product thus obtained by 33,000. The allowable effective pull depends not only upon the kind and quality of the belt, but also upon the operating speed; for example, the effective pull per inch of width for a single-ply belt $\frac{3}{16}$ inch thick and of good quality, may be about 65 pounds for a belt speed of 3000 feet per minute, whereas 50 to 55 pounds should not be exceeded for a speed of about 5000 feet per minute.

EFFICIENCY OF MECHANISM. The efficiency of a machine is the ratio of the power delivered by the machine to the power received by it. For example, the efficiency of an electric motor is the ratio between the power delivered by the motor to the machinery which it drives, and the power it receives from the generator. Assume, for example, that a motor receives 50 kilowatts from the generator, but that the output of the motor is only 47 kilowatts. Then, the efficiency of the motor is $47 \div 50 =$ 94 per cent. The efficiency of a machine tool is the ratio of the power consumed at the cutting tool to the power delivered by the driving belt. The efficiency of gearing is the ratio between the power obtained from the driven shaft to the power used by the driving shaft. Generally speaking, the efficiency of any machine or mechanism is the ratio of the "output" of power to the "input." The percentage of power representing the difference between the "input" and "output," has been dissipated through frictional and other mechanical losses.

Mechanical Efficiency. — If E represents the energy which a machine transforms into useful work or delivers at the driven end; L equals the energy lost through friction or dissipated in other ways; then

$$\text{Mechanical Efficiency} = \frac{E}{E + L}.$$

In this case the total energy $E + L$ is assumed to be the amount that is transformed into useful and useless work. The actual total amount of energy, however, may be considerably larger than the amount represented by $E + L$. For example, in a steam engine there are heat losses due to radiation and steam condensation, and considerable heat energy supplied to an internal combustion is dissipated either through the cooling water or direct to the atmosphere. In other classes of mechanical and electrical machinery the total energy is much larger than that represented by the amount transformed into useful and useless work.

Absolute Efficiency. — If E_1 equals the full amount of energy or the true total, then

$$\text{Absolute Efficiency} = \frac{E}{E_1}.$$

It is evident that absolute efficiency of a prime mover, such as a steam or gas engine, will be much lower than the mechanical efficiency. Ordinarily, the term efficiency as applied to engines and other classes of machinery, means the mechanical efficiency. The brake horsepower of a steam engine or energy delivered to the fly-wheel, divided by the indicated horsepower or work done in the steam cylinder (as shown by an indicator card) equals the mechanical efficiency. This efficiency should be determined at full load. In the case of manufacturing machinery the energy available at the driven or working end divided by the energy supplied to the initial driving shaft equals the mechanical efficiency.

Efficiencies of Different Mechanisms. — The efficiency of a given machine or machine element sometimes varies over a fairly wide range. Such variations may be due to different operating conditions, to differences in workmanship, or to variations in the design of a machine or machine element of the same general class; hence, the specific figures which follow are merely intended to serve as a general guide and indicate, as far as possible, efficiencies under average conditions. The efficiencies of ordinary or plain bearings usually vary from 95 to 98 per cent. Roller bearings and ball bearings have efficiencies of about 98 to 99 per cent.

Spur gears with cut teeth and with bearings included have an efficiency of about 96 per cent, whereas bevel gears may have about 1 per cent less, or 95 per cent. Belt drive efficiencies range from 96 to 98 per cent; roller chain drives, from 95 to 97 per cent; and high-class silent chain transmissions, from 97 to 99 per cent.

The mechanical efficiency of reciprocating steam engines varies from 85 to 95 per cent, but the *thermal* efficiency ranges from 5 to 25 per cent, the smaller figure representing non-condensing engines of the cheaper class and the higher figure the best types. Direct-acting pumps have

mechanical efficiencies ranging from 50 to 85 per cent, the efficiency increasing with the pump size and length of stroke, there being much larger frictional losses in the small sizes. Pumps of the crank and fly-wheel type have an efficiency of 85 to 90 per cent.

EFFICIENCY, POWER PLANT. See Power Plant Efficiency.

EGG COAL. Coal in pieces of such size that they will not pass a screen of 2-inch mesh, but will pass a screen of $2\frac{3}{4}$-inch mesh.

EHRHARDT PROCESS. This is a process of producing seamless tubing in which a piercing bar is forced into a solid billet, the cross-section of which corresponds to the area of the tubing to be made. This billet, heated to a white heat, is placed in a form which corresponds to the outer shape of the tube. The difference between the area of this form and the area of the billet must equal the area of the pierced bar. The metal forced from the center flows to the outside, occupying the space between the original billet and the form, which is equal to the amount of material displaced by the piercing bar.

EJECTOR CONDENSER. The ejector type of condenser is so constructed that the exhaust steam from the engine is condensed by mixing it directly with the condensing water. See Condenser.

ELASTIC BONDING PROCESS. See Bonding Processes for Grinding Wheels.

ELASTIC CEMENTS. The various cements containing rubber are elastic, if the rubber is in a predominating amount; many containing boiled linseed oil, and the hectograph composition are quite elastic. The rubber and linseed-oil cement, given in the paragraph headed Acid-proof Cements, is very tough and useful for nearly all purposes except when oil vapors are to be confined. The most useful single rubber lute is probably the so-called Hart's india-rubber cement. Equal parts of raw linseed oil and pure masticated rubber are digested together by heating, and this mixture is made into a stiff putty with fine "paper stock" asbestos. It is more convenient, however, to dissolve the rubber first in carbon disulphide, and, after mixing the oil with it, to let the solvent evaporate spontaneously.

ELASTIC GRINDING WHEELS. Very narrow grinding wheels are made by the elastic process. Shellac is the principal ingredient in the bond, and the wheels made by this process are strong and have considerable elasticity, so that very thin wheels can be used safely. Wheels $\frac{1}{32}$ inch thick are manufactured. Thin elastic wheels are used for slotting and for cutting off stock such as tubing, pipes, wire, thin sheets of tin or brass, and other materials, especially when the parts are difficult to hold for

cutting with regular tools. Thicker elastic wheels are employed for saw-gumming, grinding the teeth of gears, sharpening wood-working tools, etc. They are also used for cutlery work and roll grinding, where a very smooth polished surface is desired.

ELASTIC LIMIT. When external forces act upon a material, they tend to produce stresses within it. All stresses to which a material is subjected cause a deformation. If the stress is not too great, however, the material will return to its original shape and dimensions when the external stress is removed. The property which enables a material to return to its original shape and dimensions is called *elasticity*. If a material has been stressed to such an extent that, upon the removal of the load, it does not fully return to its original shape and dimensions, its *elastic limit* has been exceeded. Up to the elastic limit, the deformation is directly proportional to the loads. When the elastic limit is exceeded, the extensions in a material under stress cease to be proportional to the loads. The elastic limit can only be determined by the skillful use of very delicate instruments and by the measurements of the extensions for small successive increments of load. It is impossible to determine the elastic limit in ordinary commercial testing. For this reason, the ultimate strength of materials is more commonly used in the calculation of strength than the elastic limit, although the value for the elastic limit is a more accurate measure of the stress-resisting properties of the material, and in all engineering designs, the load applied to the material must never be so great that the elastic limit is exceeded. The elastic limit should not be confused with the *yield point*, which is the point where the extension of a material under test increases without increase of load.

ELBOW. An elbow or " ell " is a fitting that makes an angle between adjacent pipes. The angle is always 90 degrees, unless another angle is specified. The name *branch elbow* is used to designate an elbow having a back outlet in line with one of the outlets of the " run." It is also called a " heel outlet elbow." A *double-branch elbow* is a fitting that, in a manner, looks like a tee, or as if two elbows had been shaved and then placed together, forming a shape something like the letter Y or a crotch. A *drop elbow* is a small-sized elbow that is frequently used where gas is put into a building. These fittings have wings cast on each side. The wings have small countersunk holes so that they may be fastened by wood screws to a ceiling or wall or framing timbers. A *union elbow* has a male or female union at one end. A *service elbow* has an outside thread on one end and is also known as a " street elbow."

ELECTRIC ACCUMULATOR. The expression " electric accumulator," is seldom or never used in the United States to designate a battery for

storing electrical energy, but this term is frequently so used in other English speaking countries. In the United States "storage battery" is the accepted expression.

ELECTRICAL CONDENSER. See Condenser, Electrical.

ELECTRICAL CONDUCTORS. See Conductor Materials.

ELECTRICAL DISCHARGE. Discharge, in electricity, is the equalization of the potential difference between the terminals of a condenser or other source of electricity, on their connection by a conducting medium; the term also applies to the removal of a charge from a conductor by connecting the same to the earth. *Brush discharge* is a faint luminous discharge which takes place from a positively charged pointed conductor.

ELECTRICAL HORSEPOWER EQUIVALENT. See under Horsepower.

ELECTRIC ARC. An electric arc is the luminous arc formed when a current of electricity passes from one conductor to another through a gas or vapor which has been brought to incandescence by the discharge of electricity. The conductor from which the current passes into the incandescent gas or vapor is known as the *positive electrode*, while the conductor to which the current passes is called the *negative electrode*. A common use of the electric arc in the industries is in electric arc welding.

ELECTRIC ARC FOR CUTTING METALS. For general cutting of metals by the electric arc, graphite or carbon electrodes are used with a current of from 300 to 1000 amperes, depending on the nature of the work and the cutting speed desired. Many foundries make use of arc-welding equipment for repairing defective castings, and use the same apparatus for cutting off risers and burrs from castings. For cutting rivets, currents of from 400 to 600 amperes are usually employed. When using 400 amperes, a good operator will average from 1800 to 2000 rivets, $\frac{5}{8}$ inch in diameter, in a ten-hour day. Some operators have cut as many as 2600 to 3100 rivets of this size, working on a piece-rate basis. Cutting with the electric arc is not limited to iron and steel objects, but can be applied equally well to non-ferrous metals, such as brass, bronze, and copper. In cutting copper, current values of from 800 to 1000 amperes are used, because it is necessary to concentrate the applied heat at a sufficiently high rate to melt the copper before the heat is dissipated by the high heat conductivity of this metal.

ELECTRIC BRAKES. See Brakes, Electric.

ELECTRIC CURRENTS. Electric currents have been classified by the Standards Committee of the American Institute of Electrical Engineers

as follows: A *direct current* is a unidirectional current; as ordinarily used, the term designates a practically non-pulsating current. A *pulsating current* is a current that pulsates regularly in magnitude; as ordinarily employed, the term refers to a unidirectional current. A *continuous current* is a practically non-pulsating direct current. An *alternating current* is a current that alternates regularly in direction; unless distinctly otherwise specified, the term " alternating current " refers to a periodic current with successive waves of the same shape and area. An *oscillating current* is a periodic current the frequency of which is determined by the constants of the circuit or circuits. Alternating current has the advantage over direct current in that simpler generating machines, and generally more rugged motors may be used; but the chief advantage is that it is possible to obtain and use very much higher voltages than can easily be obtained or used with direct current. Alternating current is, therefore, used whenever distant transmission of electric power is necessary.

ELECTRIC FIXTURE THREAD. The special straight electric fixture thread consists of a straight thread of the same pitches as the American standard pipe thread, but having the U. S. standard form; it is used for caps, etc. The male thread is smaller, and the female thread larger than those of the special straight-fixture pipe threads. The male thread assembles with a standard taper female thread, while the female thread assembles with a standard taper male thread. This thread is used when it is desired to have the joint " make up " on a shoulder. The gages used are straight-threaded limit gages.

ELECTRIC FURNACES. Electric furnaces may be divided into three general classes, according to the method by which the heat is generated: 1. Arc furnaces. 2. Induction furnaces. 3. Resistance furnaces. With regard to the purpose of the furnaces, they may be divided into two large groups, melting furnaces, and heating furnaces. *Arc furnaces* produce heat by means of an electric arc between two electrodes, usually of carbon. The arc furnace may be considered as a resistance furnace in which the resistor is a gas. The resistance of gas at atmospheric pressure is greater than that of any solid resistor having the same dimensions as the arc, and, therefore, the amount of heat that can be produced in a given space is greater in an arc furnace than in any other type of furnace. Arc furnaces are used mainly for melting iron or steel. The *induction furnace* may be defined as a static transformer having a low tension " winding " formed by the material to be heated. Induction furnaces are, therefore, exclusively melting furnaces.

Resistance furnaces may be divided into two types, those in which the current is conducted by the materials to be heated with or without elec-

trolysis, and those in which the current is conducted by a special resistor. The charge or the resistor is connected directly to the source of the current supply. The heat developed in both induction and resistance furnaces is generated by the passage of the current through the resistance offered by the charge in the furnace or by the special resistor. Resistance furnaces are mainly used as heating furnaces, but are also employed for melting metals and alloys having a comparatively low melting point.

A special type of furnace which, perhaps, is the most useful of all for melting materials having a low fusing point is one which embodies the principles of both the arc and the resistance furnace, or the induction and resistance furnace. In this type of furnace, the current is started by means of an arc or by means of induction, and, when once a conductor has been established by the melting charge, the heat is maintained as in a resistance furnace.

ELECTRICITY. Electricity itself cannot be defined except in a very general way. It may be said to be a form of energy, the same as light and heat. However, electrical engineering deals with what can be *done* with electricity and not with what it is. In fact, what electricity *is* does not concern the electrical engineer any more than what gravity is concerns the mechanical engineer. Strictly speaking, the exact nature of electricity is not *definitely* known at the present time but the effects due to it and the laws that these effects follow have been very thoroughly investigated and determined. Electricity may be produced either by means of batteries — devices by which chemical energy is transformed into electrical energy — or by means of electric (electromagnetic) generators — rotating machines with conductors for electricity which move with relation to magnets in such a manner that an electric current is produced. Electricity may also be produced by so-called "thermo-couples," that is, by two dissimilar metals placed in proximity to each other and subjected to temperature differences, and by "static machines," in which the electricity is produced by the rubbing of two substances against each other. These two latter methods are of comparatively small commercial importance.

ELECTRIC LIGHT INVENTION. Sir Humphrey Davey discovered in 1809 that the separation of the charcoal terminals of a powerful battery caused the formation of a brilliant electric arc, producing light that exceeded in intensity all the other known forms of light. This discovery led to the development of methods of feeding one carbon terminal toward another in order to maintain an arc, but for many years such arc lights were confined to the laboratory, since the current could only be obtained at that time from batteries. Very efficient electric lamps, however, used in conjunction with batteries, were devised by Foucault, Duboscq, Deleuil, and

others, as early as 1853. The real development, however, of the electric light began with the invention of the dynamo. Among those who made notable contributions to arc light development should be mentioned Brush, Weston, Thomson, and Houston.

Although Thomas A. Edison is credited with the invention of the incandescent light by decision of the courts, as well as popular opinion, the first incandescent light is said to have been devised in 1840 by William R. Grove, inventor of the Grove battery. In 1845 an incandescent lamp was patented in England by August King, who acted as an agent for a Mr. Starr, an American inventor. This lamp was known as the Starr-King lamp. The Jablochkov electric light was first introduced in 1876 to light the streets of Paris. William E. Sawyer applied in 1877 for a United States patent for an electric engineering and lighting system. The form of incandescent electric lamp which resembles in its main features the modern type, was patented by Edison in 1880. This lamp had a thin filament of carbon which was sealed in a vacuum so that it would not burn away but remain incandescent. The small carbon filament and its high resistance permitted proper distribution of current to a number of lamps without special regulation. Moreover, the cost of making lamps was low enough to permit discarding them when the filament was finally destroyed as the result of use. The claims of Mr. Edison were contested by William E. Sawyer and his partner Albon Man, which at first resulted in the grant of a patent to Sawyer and Man in 1885. This was followed, however, by patent litigation in the courts which terminated in 1892 in a decision by the United States Court of Appeals awarding the incandescent lamp to Edison.

ELECTRIC RAILWAY ORIGIN. The first electric railway was constructed in Berlin in 1879 by Dr. Werner Siemens. The first electric railway in the United States was constructed in 1885 and extended from Baltimore to Hampden, a distance of two miles.

ELECTRIC RIVETER. See Riveter, Electric Type.

ELECTRIC SHOCK. An accidental electric shock usually does not kill at once, and may only stun the victim and stop his breathing temporarily. The victim of an electric shock can be restored only by prompt and continued use of artificial respiration. Break the circuit immediately. With a single quick motion separate the victim from the live conductor. In doing so, the person coming to the rescue must avoid receiving a shock himself by using a dry coat, a dry rope, a dry stick or board, or any other dry non-conductor, to move the victim or the wire so as to break the electrical contact. If the body of the victim must be touched by the hands, cover them with rubber gloves, a mackintosh, a rubber sheet, or thick, dry cloth. Also stand whenever possible on a dry board or some other

dry insulating surface, and, if possible, use only one hand. If the victim is conducting the current to the ground and he is convulsively clutching the live conductor, it is easier to shut off the current by lifting him from the ground than by trying to break his grasp. Open the nearest switch, if that is the quickest way of breaking the circuit; if necessary, cut the live wire by using a hatchet or an axe with a dry wooden handle or properly insulated pliers. As soon as the patient is clear of the live conductor, begin artificial respiration at once. *Every moment of delay is dangerous.* Continual artificial respiration is necessary without interruption until breathing is restored; even after natural breathing begins, carefully watch that it continues. If it stops, start artificial respiration again. During the period of operation, keep the victim warm by applying proper covering and by laying bottles or rubber bags filled with warm (not hot) water beside his body. Do not give the patient any liquids whatever in the mouth until he is fully conscious.

ELECTRIC SOLDERING. The general method of electric soldering consists of holding the pieces to be joined by clamping jaws with the ends of the work in firm contact; a heavy current of electricity, regulated to heat the joint sufficiently to melt the solder, is next passed through the work. The solder, in the form of tape or wire, is then applied to the joint. It flows in and around all parts heated to the proper temperature, as when using a gas flame, but the " life " or temper is retained in pieces that have been electrically soldered, instead of their being left in an annealed condition as when heated with a flame. Practically all the metals, such as brass, copper, steel, German silver, gold, and silver can be soldered successfully by means of the electric soldering process; this method is the most economical for a continuous run of work. The current used for electrical soldering should be a single-phase alternating current of any frequency between 40 and 60. A higher frequency could be used, but it is not good practice.

ELECTRIC STEEL. Electric steel is so called because it is made in some type of electric furnace. The charge of raw material may be melted in the electric furnace, or the latter may be used for refining molten metal which has been partly refined in the open-hearth furnace. In some cases, the Bessemer converter is also used. The smaller electric furnaces melt cold charges, but some of the larger installations receive the metal in a molten condition. The electric furnace produces high-grade steels and it may be used for making special alloy steels, tool steel, steel castings, and for certain other metallurgical processes. Steel may be produced in the electric furnace that is chemically purer than steel made by any other process.

ELECTRIC WELDING. In electric welding processes, the parts to be welded together are heated to a welding temperature by means of an electric current. There are two main systems of electric welding: (1) Electric resistance welding; (2) electric arc welding.

Thomson Process. — The Thomson or resistance process consists in forcing through the parts to be welded such a large volume of current that the resistance of the work is sufficient to cause fusion and welding of the metals. The parts to be welded are held between two clamping members of the welding machine, which form terminals for an electric current of low voltage and high amperage. When these clamps are forced together, the work completes the circuit, and current is transmitted directly through it from one electrode to the other. With this method of welding, the interior of the metal is raised to a welding temperature before the surface reaches that heat, and the heat generation is so rapid that the loss is negligible.

Welding Properties of Different Metals. — Various metals and alloys may be welded by the resistance process. Some combinations of different metals that have been successfully welded together by the Thomson electric welding process, are as follows: *Copper* to brass, silver, German silver, or gold; *brass* to iron, tin, mild steel, German silver, or platinum; *iron* to mild steel, tool steel, cast steel, alloy steel, cast brass, nickel, or German silver; *mild steel* to tool steel; *nickel steel* to machine steel; *tin* to zinc, brass or lead; *gold* to silver, German silver or platinum; *steel* to platinum; *silver* to platinum.

Current Used. — A single-phase alternating current of any commercial frequency may be used for the resistance process. The voltage is usually 220 or 440 and the frequency, 60 cycles, although higher voltages and lower frequencies can be employed. Where there is a multi-phase circuit, the welding machine can be connected to one phase of the circuit. Direct current is not adapted to resistance welding, because there is no way of reducing the voltage without interposing resistance which wastes power. To obtain the low voltage for welding, a special transformer inside the machine reduces the 220 or 440 volts, as the case may be, down to from 3 to 5 volts.

Arc Welding. — In welding by the electric arc process, an electrode and the object to be welded are connected in a simple electric circuit, and an arc of limited size is drawn between the two by bringing the electrode in contact with the work at the point at which the weld is to be made. The size of the arc depends upon the classes and conditions of work. The arc drawn between the electrode and the work heats the latter to the point of fusion. This method is used for cutting or burning off metal, and is the simplest application of the arc. Its principal use is for reducing scrap

material to sizes capable of being easily handled, and in foundries for cutting risers and fins from large castings. By extending this process of fusion and introducing metal within the influence of the arc, welding or building up of the work is accomplished. The metal supplied may be either in the form of a rod held in the operator's hand or it may be obtained by using a metallic electrode. The metal in either case is fused and unites with that part of the work already raised to a molten state by the heat of the arc, forming a solid mass of even structure upon cooling.

Electrodes for Arc Welding. — Graphite arc welding is the application of the heat from the arc, between a graphite rod and the work, or between two graphite rods to melt third metal, very similar to the process of gas welding. Metallic arc welding is the application of the intense heat of the arc so as to directly melt the metal electrode into a fused bowl on the work at the other end of the arc. Metallic electrodes are used for a large percentage of the work welded by the electric arc process. They may be of soft Norwegian or Swedish iron, or low-carbon steel. The diameter of the electrode depends upon the current used and the class of work. The diameters ordinarily required are $\frac{1}{8}$ inch, $\frac{5}{32}$ inch, and $\frac{3}{16}$ inch. A coated electrode has a coating of some kind applied to its surface for the purpose of improving the metal in the weld by totally or partially excluding the atmosphere from the metal while in a molten condition as it passes through the arc and after it has been deposited. By employing such coatings, it has been possible to use special alloy steel electrodes such as manganese steel, nickel steel, vanadium steel and tungsten steel. Carbon or graphite electrodes are used in welding thick plates or when it is desired to heat over large areas and add considerable metal. The carbon electrode is adapted for filling holes in large castings and for similar work, and it is especially suited to welding cast iron and non-ferrous metals and also for cutting or melting metals. The carbon pencil may vary from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inch in diameter.

Current for Arc Welding. — Some types of arc welding apparatus require a direct current and other types an alternating current. Opinions differ in regard to the relative merits of the direct and alternating current systems. A universal welding machine has been developed which can be used in connection with any industrial power supply, either alternating or direct current of 60, 40, or 25 cycles. The combination of 110, 220, and 440 voltages is obtained by multiple, series multiple, and series combinations of the coils of the primary winding. To make the same machine operate on 25 and 40 cycles, taps and adapter windings are used. The apparatus is made operative on 110- and 220-volt direct current by means of a resistor-reactor combination inserted in the secondary winding.

Metals Welded by Arc Process. — The metals which are best adapted

to the arc welding process are wrought iron, low-carbon steels and steel castings. Steel that is high in carbon can be welded only with difficulty. While cast iron can be welded, greater skill is required and pre-heating is often desirable, especially for castings of intricate form. Brass or bronze having less than 3 per cent zinc and also copper can be successfully welded if the work is done carefully, but brass having a high percentage of zinc is liable to have a porous weld, as the zinc volatilizes at comparatively low temperatures. Aluminum is very difficult to weld because it oxidizes readily at a temperature below its melting point, while the fusing point of the oxide is considerably higher.

ELECTROCHEMICAL CLEANING. Alkaline substances, such as sodium carbonate, potassium carbonate, potassium hydroxide, and sodium hydroxide in solution in varying degrees of concentration, and with small portions of potassium cyanide, develop sufficient hydrogen, with a current of from 4 to 8 volts, with the bath at nearly boiling temperature, to entirely remove all organic substances from the surface of metal, leaving it chemically clean. The action of an electro-cleanser is similar to the action of an electroplating bath. The only difference, as far as the development of gases is concerned, is that no metal being in solution and the anode being insoluble, no metal is deposited; but with a strong current a copious supply of oxyhydrogen gas is developed and attacks the organic matter upon the surfaces of articles to be cleaned, practically lifting off this matter and, by rapid evolution of the gases, carrying it to the surface. The small quantity of potassium cyanide contained in solution absorbs the slight oxidation that might be upon the surface, and by the combined action produces a surface clean enough, after washing in clear water, for any deposits.

The electrochemical cleaning solution should consist (for ordinary purposes) of from 3 to 4 ounces of caustic potash to each gallon of water, and to every 100 gallons of solution, 8 ounces of cyanide of potassium. This can be varied according to conditions. It is advisable to add at least $\frac{1}{4}$ pound of cyanide each week. Where the articles, such as iron or steel, contain much oil or grease upon the surface, the density of the solution can be increased. For articles of brass, copper, or bronze that have been polished, use a solution of carbonate of soda in the proportion of 2 ounces of soda and $\frac{1}{2}$ ounce of caustic potash to each gallon of water, with the addition of 4 ounces of cyanide to every 100 gallons of solution.

ELECTROCHEMICAL EQUIVALENT. The factor 0.001118 is called the *electrochemical equivalent* of silver; the electrochemical equivalent of other metals will be found in standard chemical and electrical handbooks. There is a simple relation between the electrochemical equivalent of various

metals and their atomic weights and valences, which is as follows:

$$\text{Electrochemical equivalent} = \frac{\text{atomic weight}}{\text{valence} \times 96{,}540}.$$

The atomic weight divided by the valence is known as the *chemical equivalent* and the factor 96,540 is known as the *faraday*. The weight, in grams, of a substance carried to an electrode by electrolytic action always equals the electrochemical equivalent of that substance multiplied by the number of coulombs passed through the cell.

ELECTROCHROMA. Electrochroma is a plating process for obtaining various colors on metals and alloys by electrolytic action. It is possible to produce various shades of green, blue, red, violet, yellow, or black by immersion of from one-half to two minutes in the electrolyte. The work is made the cathode.

ELECTRODE. The poles or terminals of an electric battery are known as *electrodes*. The pole or terminal which is at the higher potential is called the *positive pole* or *terminal*, while the other pole is the *negative pole* or *terminal*. The positive pole is known as the *cathode* and is the negative electrode, while the negative pole or *anode* is the positive electrode. In a copper-zinc battery, for example, the copper is the positive pole, but the negative electrode or plate.

ELECTRO-DEPOSITION ON WORN PARTS. A simple process, developed at the Westinghouse Research Laboratory, for building up worn parts by the electro-deposition of iron, has been used for shafts, pins, bolts, gear centers and similar parts, and with very little modification can be employed to build up the worn surfaces inside automobile engine cylinders. Commercial salts are used and a current of sufficient density is employed to permit all ordinary repair work to be removed from the plating bath at the end of two or three hours. The cost of building up and machining is kept low enough so that it will pay to reclaim a piece with this process rather than use a new one.

The Plating Bath. — A plating bath made up in the following proportions has proved best: 2.5 pounds of commercial ferrous ammonium sulphate per gallon of city water plus a small amount of ferrous carbonate (freshly precipitated and kept under water in order to keep the solution practically neutral) plus a small amount of powdered charcoal, which helps to prevent pitting.

The Process. — All small pieces are plated in earthenware crocks, and large pieces in lead-lined wooden tanks or stoneware tanks. Waterproof cement tanks can also be used. The anodes are made of "Armco" iron, cylindrical in shape. Micarta disks with a hole cut in the center are fitted

in each end of the anodes. The pieces to be plated are made the cathode and held stationary so that they extend into the plating solution through the holes in the micarta disks. The anodes are attached to a device which moves them up and down, thus keeping the plating solution stirred and the ferrous carbonate and charcoal in suspension. The temperature is held at approximately 60 degrees C., a few degrees variation either way not doing any harm. A current density of 0.43 ampere per square inch is used. This deposits metal at a rate that increases the diameter 0.006 inch per hour. This method of procedure applies only to pieces such as shafts, bolts, pins, etc.

Plating Inner Surfaces. — For pieces such as gear centers, automobile cylinders, etc., where the inside diameter needs to be reduced, the anode is made to go down through the center, and micarta rings are fastened to the anode to obtain the required stirring. The current density could be raised considerably, but as the density specified adds the deposited material at the rate of 0.003 inch on a side or increases the diameter at the rate of 0.006 inch per hour, it is evident that the ordinary repair job requiring an increase in diameter of approximately 0.010 inch to 0.020 inch can be quickly completed. It is impossible to build up a piece accurately to size, and so it is necessary to build the work up a few thousandths over-size and then turn or grind it to the finish size. This method of recovery can be used with steel or cast iron, and the deposited material can be case-hardened when necessary.

ELECTRODES, WELDING. See under Electric Welding; also Elkonite Electrodes.

ELECTRODYNAMOMETER. The electrodynamometer is used in electrical laboratories for the measuring of electric current and power, especially in alternating-current practice. The instrument depends upon the action of one circuit carrying current upon another circuit carrying the same current. The working parts of the instrument consist simply of two coils, one fixed and the other movable, together with the required indicating means. Commercial instruments of this type for measuring currents are suitable for measurements as small as 0.02 ampere. When properly calibrated and used, the readings of a Siemens electrodynamometer may be relied upon to be accurate within 0.1 per cent, for a full-scale deflection. For smaller deflections, the accuracy is not quite so great.

ELECTRO-ETCHING. Etching may be done by the use of electricity. When the wires leading from the poles of an electric battery are placed in a solution of copper sulphate, and a copper plate is attached to the positive wire, the object to be plated being attached to the negative, an electroplating outfit is formed. The deposition of a metal will not take

place on any substance but a metallic one, and it is this fact which makes it possible to employ electricity in etching. When the battery is in action, the copper is taken from the anode, or article attached to the positive wire, and deposited on the cathode or article attached to the negative wire. First let it be assumed that a piece of sheet copper is used as a cathode. In the ordinary course of procedure, the copper from the anode, when properly regulated, will be removed and deposited in a fairly even surface on the cathode. Now suppose that a design is painted on the anode like the letter A with wax, varnish, or any substance that will not be affected by the solution. When the current is flowing, the copper will be removed only from the exposed surface of the anode; the protected surface will not be affected. In consequence, it will be found that after a time the design will stand out in relief. This illustrates the principle, but the method may be varied; for instance, the background may be coated instead of the design, in which case the figure will be etched and the ground will stand out. Also, the operation may be performed on the cathode instead of on the anode, in which case the exposed parts are built up. The variations possible in using this process may be shown by the following example: Expose the letter A on an anode of copper or gold. The result will be that the letter will appear in relief. It should then be carefully rinsed in clean water without disturbing the ground. Suppose, for instance, that gold is used and it is exposed on the cathode in a silver bath, the silver being deposited in place of the gold that has been removed. Removing the piece from the bath and cleaning, the letter A is found designed in silver on a background of gold. This method is, of course, applicable to any combination of metals.

ELECTROLYSIS. The corrosion of metal in the earth or in structures, due to the action of stray or leakage currents from conductors carrying electric energy, is caused by electrolysis. Electrolytic corrosion of underground structures occurs, in general, wherever current flows from the metallic structure into the earth. Many methods have been proposed or tried for reducing or eliminating damage to pipe systems and other subsurface metallic structures due to stray earth currents from street railways. Some of these have been used widely with more or less benefit in many instances, and with apparent failure in others. There are various means by which electrolysis may be mitigated, which are applicable to the negative return of a railway system; these include the use of an alternating-current system; use of double-trolley systems; use of negative trolley; periodic reversal of trolley polarity; methods of construction and maintenance of way; grounding of tracks and negative bus; uninsulated negative feeders; insulated negative feeders without boosters; insulated negative feeders with boosters; use of three-wire systems; and location of power houses and sub-stations.

ELECTROLYTE. The liquid in a primary cell or battery, or in a storage battery.

ELECTROLYTIC COPPER. This is copper that has been refined by the electrolytic method. Such copper ordinarily contains 99.9 per cent of pure copper and has an electric conductivity of about 97 (silver = 100). The electrolytic method for refining copper consists simply in electrolytic deposition of copper on the cathode while the impurities fall to the bottom of the tank with the slime. On account of its purity, electrolytically deposited copper demands a higher price than other copper, except Lake Superior native copper.

ELECTROLYTIC REFINING. The process of electrolytic refining consists in electrolyzing anodes of the impure metal in a solution of some suitable salt of the metal, starting with cathodes of the pure metal. The metal to be refined dissolves at the anode, passes through the solution, and is deposited on the cathode in a higher degree of purity. The impurities are separated from the principal metal both at the anode and at the cathode. The most important metal refined by the electrolytic process is copper. Copper is refined to recover the valuable impurities, such as gold, silver, and platinum, and to increase the electric conductivity of the copper, for use in electric machines and the transmission of power. Very small amounts of impurities considerably reduce the conductivity. A solution of sulphuric acid and copper sulphate is used in copper refining as the electrolyte. To this mixture, from 0.01 to 0.02 per cent of glue is added so as to cause the copper to be deposited more evenly.

ELECTROMAGNETIC HARDNESS TESTING. With an electromagnetic hardness testing instrument it is possible to determine the hardness of paramagnetic metals, such as iron and steel, through the magnetic capacity of the metal. The action of the instrument depends upon the following laws, which hold with every variety of iron and steel: The magnetic capacity is directly proportional to the softness of molecular freedom. The resistance to a feeble external magnetic force is directly as the hardness or molecular rigidity. It has been shown, by direct experiments, that the molecules of iron are magnets, and that the cohesive force of each molecule is governed by the magnetic force. The cohesive force of the molecules determines the strength and properties of the metals; consequently, when the respective governing forces are measured, the true value of the quality of the metal will be determined.

ELECTROMAGNETS. A conductor carrying an electric current creates a magnetic field around it. If the wire or conductor carrying the current is wound in the form of a loop, the magnetic field intensity inside of the

loop will be much greater than that outside, because the magnetizing force of the entire loop is concentrated within that space. If several turns are made, forming a coil, each turn will add its share of magnetizing force, and produce a field of strong intensity inside of the coil. Now, if an iron bar is placed in the center of this coil, it will be magnetized, the total flux being greatly increased. The combination of the coil and iron core is called an *electromagnet*. The winding need not be distributed over the whole core, but may be concentrated in a coil in any convenient manner; and either a large electric current and a few turns of wire or a small current and many turns of wire may be used to produce the same amount of magnetizing force. An electromagnet has poles the same as a permanent magnet. The poles will depend upon the direction of the winding and the passage of the current through the conductor.

Electromagnets are used generally where there is a relatively small movement of the armature and a small air gap, such as for operating telephones, electric horns, bells, controller mechanism, automatic switches, etc. They are also used extensively on switchboards of both direct and alternating circuits, and are seen in operation in almost every manufacturing plant. Direct-current magnets have soft iron cores, and their armatures do not require any pole-shading devices like the alternating-current magnets.

ELECTROMAGNETS FOR ALTERNATING CURRENT. Some electromagnets are designed to utilize alternating current. The pole shader in an alternating-current magnet is a short-circuiting ring embedded in the pole face to retard the time-phase relation of the magnetic flux within the ring so that there is, at every instant, enough magnetism to hold the magnet closed. The pole face of an alternating-current magnet to have the same pull as a direct-current magnet must have twice the area. Where the magnetic density is not great, it is safe to use cast iron for the cores of an alternating-current magnet, but where the density is high, sheet-iron laminated cores should be used. In all magnets of sixty cycles, where the density is high, transformer iron should be employed.

ELECTROMETALLURGY. Metallurgy may be defined as the art of extracting metals from ores, and refining them to the purity required for commercial purposes. Metallurgical operations are, in general, chemical operations, because ores, with few exceptions, contain the metals as chemical compounds, and, therefore, it is usually necessary to decompose the compounds by chemical reagents. *Electrometallurgy* is the art of utilizing the electric current in obtaining metals from their ores or for refining them for industrial purposes. The methods used in electrometallurgy may be divided into electrolytic and electrothermal. Each of these methods embrace several processes.

ELECTROMETER. An electrometer is an electrical instrument for measuring differences of potentials. This instrument operates by means of electrostatic forces giving the measurements either in arbitrary or in absolute units. There are three classes of electrometers: 1. Repulsion electrometers. 2. Attracted-disk electrometers. 3. Symmetrical electrometers. See also Electroscope.

ELECTROMOTIVE FORCE. The work done in moving a positive charge of electric current around any closed path or circuit in an electric field is defined as the "electromotive force" acting around this path. The electromotive force is generally abbreviated E.M.F. In a strictly correct mechanical sense, electromotive force is not a force, but should rather be defined as work per unit charge. The unit for measuring electromotive force is called a volt, one volt being the electromotive force required to produce one ampere of current against the resistance of one ohm.

ELECTRON METAL. Electron metal, a very light constructional metal, was first placed on the market in 1909 by the Griesheim-Elektron works in Germany. It is an alloy of magnesium, having a specific gravity but two-thirds that of aluminum, with great tensile strength and machinability. The fact that it contained magnesium caused much prejudice against its use at first, most people only knowing that metal in the shape of wire or powder of great combustibility. It is true that electron metal, after melting, is very oxidizable, its blinding white light being characteristic, but, as its melting point is as high as that of aluminum — about 1200 degrees F. — its combustibility need not be considered unless the metal is to be used under exceptional conditions as to temperature. Of this the greatest proof is afforded by its use in internal-combustion engine pistons, where it is constantly exposed to the exploding gases. Its chemical character restricts its sphere of application, being unsuitable for articles which are in constant contact with running water, acids, or acid solutions. When exposed to the atmosphere, a gray coating of rust forms, but this coating does not, like iron rust, extend further into the metal, which is, in the case of electron metal, saved from further attack. The application of oil or grease entirely prevents the formation of such a coating.

ELECTRON THEORY. According to the "electron theory," matter is composed of atoms, which, in turn, are made up of electrons in very much the same way that stars and planets form solar systems. The atoms of various materials differ only in the number of electrons they contain and in the arrangement of these electrons into systems, as the electrons are apparently the same in all matter. It is thought that the electrons are of two kinds, *positive* and *negative*, and that the positive electrons act as the central suns around which the negative electrons move, as planets.

Free electrons also exist, like comets, and atoms may throw off and interchange electrons, particularly if hot, as the movement of the electrons is more rapid when the substance is hot (although it might be better to say that the substance is hot when the movement of the electrons is rapid). An electric current passing through a wire may be considered as the flow of negative electrons from one atom to another in a certain direction. This does not mean that the same electrons are supposed to travel the length of the wire, but that, if an extra electron is forced into one atom, that atom, in order to receive it, must expel one of its electrons, which is thus forced into the next atom beyond. There is so little lost motion in this transmission, however, that the transferring of electrons is accomplished along the wire with the speed of light, or 188,000 miles per second.

ELECTROPLATING. Electroplating is the art of making electrolytic depositions of one metal on another for the purpose of improving the appearance of the metal covered, or the wearing qualities, or both. In order to deposit one metal on another in a smooth, firmly adhering layer, the surface to be covered must be perfectly clean and the electrodeposition must be carried out under the proper conditions. There are five factors that determine whether or not the metal deposit is of a smooth, firm, adherent character: 1. The kind of dissolved salt from which the metal is deposited. 2. The strength of the solution. 3. The temperature of the solution. 4. The current density on the cathode. 5. The thickness of the deposit. The operation of plating consists of the following: 1. Cleaning and smoothing of the surface to be plated. 2. The electrodeposition of the metal. 3. The final polishing.

The tanks for the electrodeposition are usually made of wood when large sizes are required. They are lined with lead, or with some specially prepared compound obtainable from dealers in platers' supplies.

The anodes and cathodes are suspended from metal bars running lengthwise of the tanks. The cathodes are suspended between two rows of anodes so that the metal will be deposited evenly on both sides. The cathodes are suspended from the metal rods by means of soft copper wire. Very small objects, such as tacks, pins, and screws may be placed in a metal basket and suspended from the cathode rod, or a drum with nonconducting, perforated walls may be used. The anodes are of the same metal as that which is to be deposited.

The water used to make up the plating solutions should be clear and pure; usually the water supply of modern cities is sufficiently pure for the purpose. The chemicals used should also be of a fairly high grade of purity. The thickness of the deposit depends upon the current density and the duration of the plating. The value of the current density can be varied only within certain limits that have been found to give good deposits. In

plating an uneven surface, more metal deposits on the elevated portions and on the edges than in the depressions; the variation in thickness may be as much as 1 to 10 for different parts of the surface.

Nickel is extensively used in electroplating because of its good wearing qualities, pleasing appearance when polished, the fact that it is not blackened by sulphur compounds, and its very slight tendency to oxidize even in the presence of moisture. It is, however, attacked by hot fats and is stained by vinegar, beer, mustard, and tea. Nickel is usually plated from a solution of nickel ammonium sulphate, with some ammonium sulphate added to increase the conductivity of the solution. The bath may be made up of the following composition: Nickel ammonium sulphate, 17 ounces; ammonium sulphate, 17 ounces; water, 10 quarts. The solution should be just acid enough to redden blue litmus paper. This bath requires about 2 volts, and the proper current density is about 5.5 amperes per square foot. The deposit of nickel, and of other metals also, is more adhesive when a higher potential, for example, 6 volts, is used for the first 30 seconds. Plating with copper is usually for the purpose of preparing the more electropositive metals, such as zinc, iron, and tin, for the process of nickeling, silvering, or gilding; more rarely to protect them from oxidation, or for decoration.

ELECTRO-POSITIVE. Of the various methods used to protect iron from corroding or rusting, the application of a zinc surface is one of the most effective. This is due to the fact that zinc is one of the few moderate-priced metals which is electro-positive to iron. To understand the meaning of this statement, it is necessary to know what takes place during the corrosion of a piece of iron or steel that is protected by a coating of some other metal. The corrosive action is started by the setting up of a galvanic electric current, which results in carrying metal to the negative pole of the electrolytic cell. In the case of zinc, which is electro-positive to iron, a galvanic action of this kind causes a slight depletion of the zinc at points where such an action is proceeding, but does not damage the iron. With iron or steel products covered with a coating of some metal which is electro-negative to iron, the result of such a galvanic action would be the reverse; namely, there would be a depletion of the iron beneath the coating of the second metal which covers the work. It is of interest to note that the corrosive action caused by a galvanic current can only take place where there is a flaw in the coating of zinc or other metal with which the iron is covered, that allows moisture to gather. But as it is practically impossible to produce a coating in which there are not at least a few very small openings, the effect of the galvanic action that takes place at such points becomes a matter of importance.

ELECTROSCOPE. The electroscope is an instrument used for detecting the presence of an electric charge, or, in other words, differences of electrical potential or electrification. One of the earliest forms of electroscope consisted of a light metallic needle balanced on a pivot the same as a compass needle. An improvement on this type consisted in simple forms of repulsion electroscopes, in which two similar electrified bodies repelled each other. The uses of the electroscope are to ascertain if any body is in a state of electrification and to indicate whether the charge is positive or negative. See also Electrometer.

ELECTROTYPING. Electrotyping is an application of electroplating used in the printing industries for copying engraved plates or type matter. A copper plate is made, by means of the electrotyping process, which is an exact duplicate of the engraving or of type matter which has been set up ready for printing.

ELECTRUM. Same as German Silver.

ELEMENT. In chemistry, an element is a substance which consists of chemically united atoms of one kind. The substance cannot be changed by chemical action into some other substance or substances, except by the addition of some other element that can combine with the atoms of the original element; hence, iron, lead, sulphur, hydrogen, etc., are elements.

ELEVATOR ROPE. Elevator rope is a name given to a wire rope usually made of iron and composed of 6 strands of 19 wires each, having a hemp core in the center of the rope. This kind of rope is used, to a large extent, as a hoisting rope for elevators; hence, the name.

ELKONITE ELECTRODES. Copper is ideal as electrode material, insofar as electrical conductivity is concerned, but for many classes of service it is lacking in strength and durability and for certain applications its use is entirely impracticable. The pressures which must be applied for some welding operations are so high that copper electrodes are rapidly compressed and distorted, especially after being annealed by the heat incident to welding; consequently, the contact area is increased, thus decreasing the resistance to current flow and the amount of heat generated. As a result the quality of the weld is impaired, unless provision is made for increasing the amount of current to offset the increase in contact area. In other applications where the electrodes are utilized to accurately locate the parts to be welded, the deformation of the electrodes due to clamping pressures and compression of the metal, results in gradually changing the location of the parts so that the work is done inaccurately.

The difficulties referred to in connection with copper electrodes, have been overcome by the introduction of electrodes composed of tungsten

and copper in proportions that are varied to suit the class of service. This electrode material is known as "Elkonite." It is not a true alloy, but rather a mechanical mixture of tungsten and copper. For some purposes there is 50 per cent of tungsten and 50 per cent of copper, whereas for other applications the tungsten content is increased up to 80 per cent.

Elkonite electrodes are from about 100 to approximately 500 times more durable than copper electrodes. They are especially recommended for operations requiring either higher compressive strength than copper, or a somewhat higher resistance. The latter, for instance, is a factor in welding satisfactorily certain non-ferrous metals such, for example, as aluminum. This type of electrode consists of an Elkonite insert only, the main body being of copper.

ELLIPSOGRAPH. The ellipsograph is an instrument employed for drawing ellipses on the drafting-board. A number of different designs have been developed, some of which are obtainable as commercial products in the market.

ELLIPSOID. An ellipsoid is a solid body of such shape that all the sections passing through its center are ellipses. If the ellipsoid is formed by an ellipse rotating about its major axis, all the sections on planes parallel to the minor axis of the generating ellipse will be circles, and the solid body so formed is known as an *ellipsoid of revolution*, or a *spheroid*.

ELLIPTICAL CHUCKS. Elliptical chucks are made in several different designs by various manufacturers. They impart an elliptical motion to the work. They are used to a limited extent in machine and tool work and much more extensively in wood-working and metal spinning. In die-making elliptical chucks are useful for turning or boring oval punches and dies. For wood-working, elliptical chucks are used for such operations as the turning of oval frames and in connection with ornamental work. Chucks of this type are also used for metal spinning in order to produce the various elliptical and oval shapes in which sheet metal parts are made.

ELLIPTIC GEARS. One of the simplest means for producing a quick-return motion, as used on shapers, slotters, shears, punches, and a number of other machines, is by means of *elliptic gears*, that is, gears having a pitch line of elliptical shape. When elliptic gears are used, the two gears that mesh with each other must be equal in size, and they must revolve on one of the foci of the ellipse forming the pitch line.

ELLIPTIC SPRINGS. An elliptic spring generally consists of a number of flat leaf springs so arranged that the supports are at both ends of the flat leaves and the loads applied in the center. The leaves are generally slightly curved in the making, giving them the shape of an elliptic arc,

so that the load, when applied, tends to straighten the leaves. Elliptic springs may be either *half-elliptic*, also known as semi-elliptic, or *full-elliptic*, according to whether they are made up of one or two sets of curved leaves.

ELMORE PROCESS. The Elmore process is an electrolytic process for making copper tubes by depositing copper on a conducting cylinder rotating in an acid copper-sulphate bath. The surface of the conducting cylinder is prepared so that the copper will not stick so firmly that the tubes cannot be slipped off the cylinder when finished. The outer surface of the tube being deposited is kept smooth by frequent polishing during the deposition of copper. Copper sheets may be made by the same process by making the cylinders on which the copper is deposited of large diameter, so that the tubes become large enough to be cut open and spread out.

ELONGATION AND REDUCTION OF AREA. When a piece of material is tested for tensile strength in a testing machine, it elongates a certain amount before rupture takes place. This elongation constitutes an important quality in the material, as it indicates its toughness or the degree to which the material is likely to give warning before it will actually break. It is measured as the percentage of stretch or *elongation* occurring in a given length of the original piece; this length is frequently assumed as two inches. For example, if a test-piece 2 inches long is found to be $2\frac{1}{4}$ inches long after rupture, the elongation in two inches is said to be $12\frac{1}{2}$ per cent. It should be noted that the recorded value of elongation for any test depends largely upon the original length selected for comparison, because the total elongation consists partly of a general extension which takes place mainly before the ultimate stress has been reached, and which is distributed fairly uniformly over the whole length of the piece, and partly of an elongation in the vicinity of the section where the rupture will occur, where the local elongation is much greater, and practically independent of the total length of the piece. At this point, the elongation is also accompanied by a marked contraction of cross-sectional area. The elongation at the time of rupture cannot be calculated, but, in every case, is found by actual tests.

A piece of material tested to failure in tension contracts or decreases in cross-sectional area at the point of rupture. The percentage of decrease of area in relation to the original normal cross-section is known as the *reduction of area*. For example, if the original cross-sectional area of a bar was 0.78 square inch, and the section, after the piece had been tested to failure, was 0.44 square inch, then the decrease of area would be 0.34 square inch and the reduction of area would be $0.34 \div 0.78 = 0.44$, or 44 per cent. The area of a round bar tested to destruction is usually computed from the mean of two diameters measured at right angles to each

other. Brittle materials fail without appreciable deformation. Thus the percentage of elongation and the reduction of area in test-pieces of brittle materials are very small. As an example may be mentioned cast iron, which will break with practically no deformation.

EMBOSSING. Embossing is the process of producing raised patterns or letters on metal surfaces. The term is also extended to the production of raised patterns on leather, paper, and other fabrics. Strictly speaking, the term should be applied only to the process of producing raised patterns or letters by means of dies or plates which are brought to bear forcibly upon the material to be embossed.

EMBOSSING AND COINING PRESSES. Some embossing operations may be done in almost any kind of power press but the heaviest work requires a machine of special design, owing to the enormous pressures necessary for this branch of die work. These pressures range from a few tons up to 1000 or 1500 tons. In the knuckle-joint embossing press, the die is fastened to a slide which is actuated by means of powerful toggles. These presses are adapted for embossing silver, britannia, brass, copper, etc., and the manufacture of medals, coin, jewelry, watches, silverware, etc.

EMBOSSING DIES. An embossing die is used to form raised letters or an ornamental design, in relief, upon the surface of the work. An embossing die differs from a forming die in that the projections or designs made by it are comparatively small or shallow, and usually in the nature of relief work upon a surface, whereas a forming die gives the required shape to the work. The formation of lettered inscriptions, symbols, and decorative designs on all kinds of sheet-metal boxes and cans is done by embossing dies. A simple form of embossing die is one used for producing the circular ridges on the heads of tin cans, etc. Such a die would have one or more annular grooves and the punch would have annular ridges of corresponding size for forcing the metal into the die grooves. Embossing is commonly done in a die designed to cut, draw, and emboss the blank in one operation. An embossing die of this kind may be either a combination, a double-action, or a triple-action type, depending upon the nature of the work and the kind of press available.

EMERSON WAGE SYSTEM. See Wage System, Emerson.

EMERY. Emery is an abrasive which has been very extensively used. At one time, practically all grinding wheels were made from it, but artificial abrasives possessing superior cutting qualities are now employed for machine grinding. Emery is obtained from Naxos (an island in the Ægean Sea); from the vicinity of Smyrna, in Turkey; and from Chester, Mass.

The value of emery as an abrasive depends upon the proportion of crystalline aluminum oxide which it contains, since this is the only element in emery which is hard enough to have any appreciable cutting action on metals. Naxos emery contains 63 per cent aluminum oxide; Smyrna or Turkish emery, 57 per cent; and Chester emery, 55 per cent.

E.M.F. This is the common abbreviation for electromotive force. See Electromotive Force.

ENAMELITE. Enamelite is the trade name originally given to a preparation used for the local hardening of steel. See Localcase and Localhard.

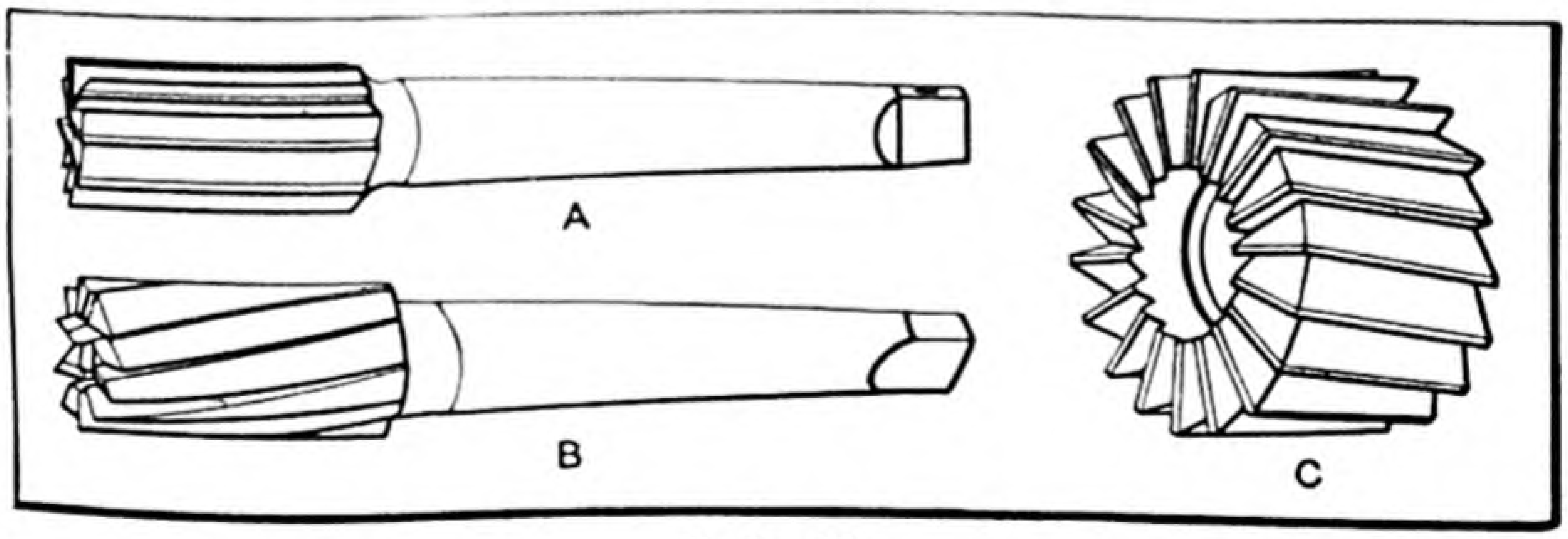
END ANGLE OF HOB. See Hob End Angle.

END-CELL SWITCHES. These are devices used in storage batteries primarily for varying the discharge voltage of the booster by varying the number of cells discharging into the load.

ENDLESS BELT. The name "endless belt" is commonly applied to a belt the sections of which are joined together by cemented lap joints, thus forming practically a continuous belt as compared with one joined by a lacing or other fastening device.

END MILLING. Surfaces are frequently machined by end-mills when it would not be feasible to use a cutter mounted on an arbor. The surface is milled by the radial teeth on the end as well as by the axial teeth, as the work is traversed at right angles to the cutter.

END-MILLS. End-mills, as shown at *A* and *B*, are provided with teeth both on the cylindrical surface and on the plain end surface; hence,



End-mills

they can cut in an endwise as well as in a sidewise direction. The cutting is mainly done by the teeth on the end surface; hence, the name. End-mills may be provided either with a solid shank by which they are driven, or with a hole through them in which an arbor fits which drives the mill. This latter type, shown at *C*, is known as a *shell end-mill*.

End-mill Flutes. — Theoretically, a right-hand cutter should have right-

hand spiral flutes, as the teeth then have positive rake. Although the right-hand flutes tend to pull the cutter out of the socket when used for side-milling, this disadvantage does not outweigh the advantage of having the cutter teeth made with positive rake. It is good practice to hold the cutter firmly in the socket by means of a threaded rod which passes through the spindle and engages the end of the cutter shank, and thus draw the cutter firmly into the spindle socket.

The fact that a left-hand spiral on a right-hand mill tends to push the cutter firmly into the socket is often considered a greater advantage than the positive rake of the right-hand spiral on a right-hand cutter. This applies only when the cutter is used for milling slots where a considerable number of the axial teeth are engaged. If the mill is used as an end cutter only, then the spiral on the right-hand cutter should be right-handed, because the teeth then have a positive front rake. Some manufacturers of milling cutters prefer, for ordinary use, end-mills having straight teeth.

ENERGY CONSERVATION. See Conservation of Energy.

ENERGY IN CHEMISTRY. The chemical combination of two or more elements could not be effected if there were in the universe nothing but matter. The combination of equal parts of hydrogen and chlorine is merely a mechanical mixture until it is exposed to light, and a combination of copper filings and sulphur is only a mechanical mixture until it is exposed to heat. In each case, however, an entirely different substance is obtained. This shows that there is present in the universe a power to perform work, called *energy*. It may manifest itself in the form of light, heat, electricity, etc. It may be changed from one form to another, but, like matter, it cannot be destroyed. In chemistry, energy effects changes in the composition of a substance, or in chemical changes.

ENERGY IN MECHANICS. A body is said to possess *energy*, in a mechanical sense, when it has the capacity of doing work — that is, of overcoming a resistance through a distance. In general, energy is something that is given to a body by doing work upon it, as when a weight is raised or is given a rapid motion, or when a spring is compressed; the energy, in turn, is given out when the body itself performs work. Energy is, therefore, sometimes defined as stored work. It is expressed in foot-pounds, the same unit that is used to express work. Energy is either potential or kinetic. *Potential energy* is the power of doing work possessed by a body in virtue of its position or condition. A compressed spring, a raised pile driver, a pendulum at the end of its stroke, and a head of water have the capacity of doing work and are therefore stored with potential energy. *Kinetic energy* is the power of doing work possessed by a body on account of its motion. A moving railroad train, a flywheel, a current of air driving

a windmill, a falling body, all possess kinetic energy. The kinetic energy of a body is obtained by multiplying one-half its mass by the square of its velocity in feet per second.

ENGINE. According to modern usage, the word "engine" is generally assumed to mean some type of prime mover, such as a steam engine or internal combustion engine. (See type such as Steam Engine, Diesel Engine, etc.) In the early stages of mechanical developments particularly, almost every mechanical device, especially if intended for the transmission of energy, was called an engine, and this broader usage of the term has survived in a few instances, as for example, engine lathe, dividing engine, dental engine, etc.

ENGINEERING. The field of work wherein scientific knowledge is applied to industrial problems has become known as the "field of engineering." Originally the term engineering was used to designate the design, construction, and operation of industrial works, but it has been extended to cover practically everything in the way of industrial work, including the problems of humanity so far as they are affected by modern industrial methods.

ENGINEER'S CHAIN. The engineer's chain used in surveying has 100 links, each 1 foot long, making the total length of the chain 100 feet. Every tenth link is provided with a brass tag marked to indicate the number of the links from the end, and the middle of the chain is marked with a round tag. Each end-link is provided with a handle, and the zero point or end of the chain is at the outside edge of the handle. Measurements made with the chain are liable to be inaccurate unless care is taken, because of sagging at the center due to its weight, and also to changes in length caused by wearing at the joints. The length of the chain is adjustable by means of a screw and nut in one of the handles, permitting the length of the end link to be changed. This corrects the error in the total length of the chain, but as the correction is made at one end only, the error is still present in the remainder of the chain. Owing to the wear and other disadvantages of measuring chains, they are gradually being displaced by heavy steel tapes. The metric chain has 100 links, each 20 centimeters long, the total length of the chain being 20 meters. See also Gunter's Chain.

ENGINE LATHE. A name commonly applied to a general-purpose metal-working lathe of the hand-manipulated type found in practically all machine shops. Such lathes are called *engine* lathes because during the early stages of lathe development, the term engine was applied quite generally to different classes of mechanism. See Lathe Classification.

ENGLISH GEAR-BRONZE. This is an alloy composed of 88.7 per cent of copper, 11 per cent of tin, and 0.3 per cent of phosphorus. It is used in the automobile industry as a material for driving gears. The phosphorus is introduced into the alloy in the form of phosphor-copper containing 15 per cent of phosphorus, so that the working formula for the preparation of the alloy is: Copper, 87 per cent; tin, 11 per cent; phosphor-copper, 2 per cent. When properly made, this bronze will have an ultimate strength of 48,000 pounds per square inch, a yield point of 26,000 pounds per square inch; a specific gravity of 8.83; and a Brinell hardness number of 82. The elongation is from 17 to 18 per cent in two inches, and the reduction of area, 18 per cent.

ENGLISH LEGAL STANDARD WIRE GAGE. This gage is used in England for all wire. It is also known as the Imperial Wire Gage, and Standard Wire Gage.

ENGRAVING MACHINES. Engraving machines are designed to reproduce the form of a pattern or model on the part to be engraved, by means of a mechanism which transmits the movement of a tracing point to a suitable cutting tool. In the operation of the machine, the tracing point is made to follow the pattern or model, usually by guiding it with the hand. There are two general types of engraving machines. On one type the tool does not revolve, but is drawn across the work so that it operates the same as a planing tool. The angular position of the graver or tool may be varied to secure different effects, and the tool-holder may also be turned on some machines so that the graver will be kept facing the changing direction of the cut, but the tool does not revolve continuously. Engraving machines of this type are extensively used by jewelers, etc., for engraving letters on silverware, name-plates, ornamental designs, and for similar operations. Engraving machines of the second class or type mentioned are equipped with rotating cutters. They are adapted more especially to the engraving of dies, steel stamps, etc., and, in some cases, for special manufacturing operations.

Engraving machines may be further classified according to the form of mechanism utilized for reproducing the pattern or model on the engraved part. Many of the types intended more particularly for engraving letters or ornate designs on nameplates, dies, silverware, etc., have a pantograph mechanism for reproducing the pattern or model on a reduced scale. Other machines of the reducing type, or those using a model that is considerably larger than the design or form to be engraved, are so arranged that the necessary reduction between the movement of the tracing point which bears against the pattern, and the tool or cutter is obtained by simply attaching the tracer and cutter head to a lever at distances from the pivot of the

lever proportional to the reduction required between the pattern and engraved part. There is still another type of engraving machine which does not have a reducing mechanism, but which operates direct, in that the tracing point bears against a model corresponding in size to the impression or surface to be engraved, and this tracing point guides the cutting tool by a direct connection with the cutter spindle or the member in which it is mounted.

ENTROPY. In thermodynamics, especially in dealing with steam, the change in entropy or in the "condition" of the water or steam is frequently referred to. The change in entropy, which results when the required amount of heat to raise one pound of water from 32 degrees F. to the boiling point (212 degrees F.) is added, is called the "entropy of the water"; the change in entropy during evaporation, that is, the heat of evaporation divided by the absolute temperature of the boiling point, is called the "entropy of evaporation"; and the entropy of the water plus the entropy of evaporation is called the "entropy of steam." The entropy of water is approximately equal to the quotient of the heat added to one pound of water to raise its temperature from 32 degrees F. to 212 degrees F., divided by the average of these two temperatures above absolute zero.

ENTZ BOOSTER. This is an electrical machine used for the charging of electric storage batteries. It is also known as a Carbon Regulator.

EPICASSIT. Epicassit is a material which is used for coating iron or steel to protect the metal against corrosion. Epicassit consists of pure tin or of lead and tin in various proportions; an alloy of lead, tin, and zinc is also used with satisfactory results. The metal alloys are reduced to a powdered condition, and this powder is mixed with so-called *epicassit fluid* to a consistency of a thick creamy paint, which is applied with a thick bristle brush, and then melted on the surface to be coated by heating the article. Any clean source of heat may be employed for the amalgamation, such as a blow-torch or a clean fire, or an oven. In making local repairs of vats, tanks, etc., or in entirely recoating worn surfaces, epicassit is particularly useful, as it avoids the necessity of dismantling the equipment, shipping it to the dipping plant, and then remounting it.

EPICYCLIC GEARING. An epicyclic or planetary gear train consists of a number of meshing gears, of which at least one revolves around a central gear, at the same time rotating about its own axis, so that the arm or bracket supporting such planetary gear, or gears, is given a definite speed of rotation by the driving gears. When the arm or bracket is the driving member of the combination, it imparts a definite speed to the driven gear, any intermediate gears or pinions simply acting as members for the transmission

of motion between the principal parts — the driving and driven members of the combination. The arrangement offers possibilities of securing high speed ratios with comparatively few gears, compactly arranged. It lends itself to many transmission problems that would otherwise be solved with difficulty and require cumbersome gearing. Adaptable and convenient as are epicyclic gear trains, their use has been largely limited to certain types of speed reducers, and special, intricate machines or mechanisms.

EPICYCLOID. An epicycloid is a curve traced or described by a point located on the circumference of a circle which rolls on the outside of the circumference of another circle. If the moving circle rolls on the inside of the periphery of another circle, a point on the circumference will trace or describe a *hypocycloid*. These mathematical curves have mechanical importance, because the teeth in the cycloidal system of gear teeth are formed according to these curves.

EQUALING FILES. This is a type of file that is made from mill sections and is nearly of blunt form, but has a very slight curvature extending from the point to the tang. These files are double-cut and mostly bastard. Equaling files are used for general shop work, but are seldom employed except for fine toolmaking.

EQUALIZING CHARGE. In storage batteries, an "equalizing charge" may be given at regular weekly or bi-weekly intervals. It is carried to the complete maximum for the purpose of equalizing all cells, reducing all sulphate, and keeping the plates in good condition generally. It is also known as Overcharge.

EQUALIZING DOG. In using a double-ended dog, care should be taken to adjust the driving pins so that there will be an equal pressure on each side. To avoid careless adjustment of the driving pins, what is known as an "equalizing dog" is sometimes used. This merely consists of two V-shaped clamps held together by bolts on opposite sides of the work and having extension driving ends. By adjusting the clamping bolts, the ends are brought firmly into contact with the driving pins. A convenient method of equalizing the pressure on the pins, when a double-ended dog is used, is by means of an auxiliary plate into which the driving pins are inserted. This plate is attached to the front of the regular faceplate by means of bolts or studs which are screwed solidly into the regular faceplate but fit loosely into slots of the driving plate. These slots are radial and in line so that if one driving pin is subjected to greater pressure, when first starting a cut, this excess pressure causes the driving plate to shift so that the pin of the opposite side is automatically adjusted.

EQUALIZING SETS. Flywheel motor-generator equalizing sets perform the function of equalizing the load on a generating plant by taking

care of the high peaks caused by fluctuating loads, such as mine hoists, etc. They usually consist of an induction motor and one or two direct-current generators with an accurately balanced cast-steel flywheel swung between them, and one or two direct-connected exciters overhung at the ends of the set. The wheel is used to store the energy when the load is light, returning it to the system when the peaks come on. The induction motor is of the phase-wound collector-ring type with a regulator in the secondary circuit so arranged that, when the supply of current to the motor increases to more than a predetermined amount, resistance is automatically inserted in the secondary motor circuit, which has the effect of limiting the current taken by the motor, and thus allowing the excess energy to be supplied by the flywheel.

EQUATIONS. An equation is a statement of equality between two expressions; thus, $5x = 105$ is an equation. Equations are used for the solution of mathematical problems. An equation is said to be of the *first degree* if it contains the unknown in the first power only. For example, $3x = 9$ is an equation of the first degree, because the unknown quantity x is in the first power. An equation which contains the unknown quantity in the second, or first and second, but no higher power, is called a *quadratic equation.* Thus, $x^2 + 3x = 18$ is a quadratic equation. An equation which contains the unknown quantity in the third power is called a *cubic equation.* Thus, $x^3 + 3x^2 + x = 22$ is a cubic equation. The solving of equations involves algebraical operations. See also Chemical Equation.

EQUIVALENT EVAPORATION. This is an expression used to designate the evaporation equivalent to any given condition, reduced to terms of the evaporation of feed water at a temperature of 212 degrees F. into steam at atmospheric pressure. This enables comparisons between evaporations from feed water at different temperatures and steam at different pressures. For example: The standard boiler horsepower in the United States is the capacity to evaporate 30 pounds of water per hour from a feed-water temperature of 100 degrees F. into dry steam at 70 pounds gage pressure. This is equivalent to the evaporation of 34.5 pounds of water at a temperature of 212 degrees F. into steam at atmospheric pressure, which corresponds to 0 pounds gage pressure.

ERG. The erg is the *unit of work* in the centimetergram-second (C.G.S.) system, also frequently known as the *absolute* system of measurement. An erg equals one dyne-centimeter, the dyne being the unit of force in the C.G.S. system, and being equal to $\frac{1}{981}$ gram. The unit of power is derived from the erg, the unit of power being one watt, which is equal to 10,000,000 ergs per second.

ERICHSEN VALUE. The term "Erichsen value" as applied to sheet metal is a factor used to indicate the workability of sheet metal. The test is conducted by supporting the sheet on a circular ring and deforming it at the center of the ring by using a spherical shaped tool. The depth of the impression or cup, in millimeters, required to obtain fracture is the Erichsen value of the metal. Erichsen standard values of sheet metals are furnished by some manufacturers for various sheet thicknesses. See Sheet-metal Testing.

ESBALITE. This is an alkaline-proof insulating paint used for painting the containers of alkaline storage batteries. To make this paint adhere properly, all surfaces to be coated by it must be cleaned perfectly free from moisture, grease, and dirt, after which the paint may be applied either by a brush or by dipping.

ESCAPEMENTS. An escapement may be considered as a form of ratchet mechanism having an oscillating double-ended pawl for controlling the motion of the ratchet wheel by engaging successive teeth. Escapements are designed to allow intermittent motion to occur at regular intervals of time. As applied to a pendulum clock the escapement serves two purposes, in that it governs the movement of the scape wheel for each swing of the pendulum and also gives the pendulum an impulse each time a tooth of the scape wheel is released. An escapement should be so arranged that the pendulum will receive an impulse for a short period at the lowest part of its swing and then be left free until the next impulse occurs. One of the earlier forms of escapements was known as the "anchor" or "recoil" escapement. With this type, the pendulum was never free, but was controlled by the escapement throughout the swing. To avoid this effect, the Graham "dead-beat" escapement was designed and has been extensively used. When the escapement is in action, the pallets (two ends of the double-ended pawl) alternately engage the teeth of the scape wheel, which revolves intermittently. In designing an escapement of this type, the pallets are so located as to embrace about one-third of the circumference of the scape wheel. One of the features of the dead-beat escapement is the effect which friction has on its operation. During each swing of the pendulum, there is a rubbing action between the points of the scape wheel teeth and the surfaces of the pallets, so that the pendulum is retarded constantly by a slight amount of friction. This friction, however, instead of being a defect, is a decided advantage, because, if the driving force of the clock is increased so that the impulse on the pallets becomes greater, the velocity of the pendulum tends to increase, but this effect is counteracted by the frictional retardation caused by a greater pressure of the teeth of the scape wheel on the faces of the pallet.

ETCHING. A common method of etching names or simple designs upon steel is to apply a thin, even coating of beeswax, or some similar substance which will resist acid; then mark the required lines or letters in the wax with a sharp-pointed scriber, thus exposing the steel (where the wax has been removed by the scriber point) to the action of an acid, which is finally applied. The proper application of the ground which is used to protect the parts from the action of the corroding fluid is very important. For general purposes, beeswax of the proper consistency is excellent, and it can be applied easily in any desired thickness. Before applying the wax, it is important that the surface be thoroughly clean and absolutely dry, and the difference in temperature between the wax and the article to be etched should be slight. If it is necessary to dip the piece into melted wax, the article should be kept immersed for a few moments until it acquires the same temperature as the molten wax. If there is a film of oil on the surface to be coated, the wax will cover it but not adhere, and in consequence the etching fluid will run under the wax and produce a smear or blur. The same effect is produced by moisture, except that in this case the blur is likely to be worse, as there is an affinity between water and etching fluid which causes spreading.

ETCHING ACIDS. The following fluids have been tried on the various substances for etching and found to work satisfactorily: *Iron and Steel:* Hydrochloric acid (full strength). *Brass:* Nitric acid. *Copper:* A mixture containing 2 parts of nitric acid and 1 part sulphuric acid. *Silver:* Nitric acid, 3 parts, water, 1 part. *Gold:* A mixture containing 1 part of nitric acid and 3 parts of hydrochloric acid. This mixture should be prepared just before being applied and should be used warm, under a hood or fume closet. *Platinum:* The same mixture as that used for gold. *Lead:* Nitric acid. *Aluminum:* A 10 per cent solution of caustic soda or potash. *Zinc:* A mixture containing equal parts of hydrochloric acid and water, used warm. *Glass:* Hydrofluoric acid. The article may be immersed in the liquid acid for a few minutes or it may be exposed to the fumes from five to fifteen minutes. Extreme caution should be used in handling this acid, using rubber gloves for the hands and a lead or hard rubber container for the acid. Contact with the skin will cause severe burns. All of these acids may be used full strength and will act instantly, but if the etching is to be of considerable depth most of them may be diluted with water before applying. This will require more time, but will produce a cleaner cut. The exception to this is the mixture for gold and platinum, which must always be used full strength and applied as warm as the melting point of the wax will permit.

ETCHING, ELECTRICAL. See Electro-etching.

ETCHING RESISTS. Various acid-resisting materials are used for covering the surfaces of steel rules, etc., prior to marking off the lines on a graduating machine. When the graduation lines are fine and very closely spaced, as on machinists' scales which are divided into hundredths or sixty-fourths, it is very important to use a thin resist that will cling to the metal and prevent any under-cutting of the acid; the resist should also enable fine lines to be drawn without tearing or crumbling as the tool passes through it. One resist that has been extensively used is composed of about 50 per cent of asphaltum, 25 per cent of beeswax, and, in addition, a small percentage of Burgundy pitch, black pitch, and turpentine. A thin covering of this resisting material is applied to the clean polished surface to be graduated and, after it is dry, the work is ready for the graduating machine. For some classes of work, paraffin is used for protecting the surface surrounding the graduation lines which are to be etched. The method of application consists in melting the paraffin and raising its temperature high enough so that it will flow freely; then the work on which the graduating is to be done is held at a slight angle and the paraffin is poured on its upper edge. As the melted paraffin flows across the surface of the work, the latter will be covered with a thin protective coating.

ETCH TEST. The etch test is a method for testing metals by microscopic inspection. The test specimen is ground or polished and then etched by a suitable acid or other etching fluid for a sufficient period to develop the structure of the metal.

EUTECTOID STEELS. A steel composed wholly of pearlite is called eutectoid, and contains about 0.90 per cent of carbon. Steel with a lower carbon content is called hypo-eutectoid and it consists of pearlite and "free" or "excess" ferrite, the amounts depending upon the carbon content. Steel containing more than about 0.90 per cent is called hyper-eutectoid and it consists of pearlite and free cementite. Eutectoid steel is also known as saturated steel.

EVAPORATION EQUIVALENT. See Equivalent Evaporation.

EVAPORATION FACTOR. The evaporation factor is the ratio between the number of heat units required for evaporating one pound of water of a given feed water temperature into steam of a given pressure, to the number of heat units required for evaporating one pound of water from a temperature of 212 degrees F. into steam at atmospheric pressure.

EVAPORATION RATE. See Rate of Evaporation.

EWART CHAIN. Same as Link-belt.

EXCITERS. Almost all synchronous machines are dependent on an external source of direct current for the magnetization of their fields, and

the machines furnishing this excitation are generally termed *exciters*. The exciters may be either direct connected to the main generators or driven separately either by prime movers or motors. Current from the exciters is led to insulated cast-iron collector rings mounted on the shaft, and then to the field winding. It is important that the total exciter capacity in a station be sufficient to magnetize all the synchronous machines when these are operating at their maximum load and true operating power factor, this excitation being considerably higher than if the machinery were only operating at normal full load and unity power factor.

EXPANDED METAL. The term "expanded metal" is applied to sheet metal which has been stretched or expanded to form a screen, by first splitting the solid sheet intermittently so that the entire sheet has a series of closely spaced parallel cuts, to permit expanding it laterally to form open screen work. Thus, as the sheet is stretched edgewise the numerous slits open and the metal between them forms a screen of diagonal pattern. Expanded metal screens are made from stock of various thicknesses and are used for concrete reinforcing, metal laths, machine guard screens, and for various other purposes.

EXPANDING-BAND CLUTCH. This is a clutch similar to the contracting-band clutch, except that its action depends upon the expansion of a band or ring which, when expanded, grips the inside of a drum surrounding it, and thus transmits power.

EXPANSION. Practically all substances expand when heated. The expansion of solid bodies in a longitudinal direction is known as the *linear expansion*. The expansion in volume is called the *volumetric expansion;* this latter equals three times the linear expansion.

If the amount that a steel rod lengthens when its temperature is increased one degree F. is known, the expansion for a greater increase of temperature may be determined readily. In engineering handbooks tables will be found which give the linear expansion of different metals and other materials, per unit of length, for an increase in temperature of one degree. This figure which is called the *coefficient of expansion*, is obtained by dividing the amount that a rod of given length expands after a one-degree rise in temperature, by the original length of the rod. For instance, if a rod 120 inches long expanded 0.0008 inch due to a one-degree F. rise in temperature, the coefficient of the linear expansion, or linear expansion per unit of length per degree F., would equal $0.0008 \div 120 = 0.00000666$. Therefore, a rod made of this particular material would increase 0.00000666 of its length for each rise in temperature of one degree F. Hence, the total amount of linear expansion may be determined by the following rule:

Rule: Multiply the length of the rod or other part by the coefficient

of expansion for that particular metal, and multiply the product by the difference between the original temperature and the temperature after heating.

EXPANSION, ADIABATIC. See Adiabatic Expansion and Compression.

EXPANSION ARBOR. This is a type of arbor the diameter of which can be decreased or increased within certain limits. Its diameter may be varied to fit varying diameter holes in parts to be machined, thereby reducing the number of arbors required for a given range of work. Many different designs of expansion arbors are found in machine shops.

EXPANSION BENDS. For low-pressure steam and exhaust mains, expansion joints of any suitable standard make may be used to take up or relieve the strains on a piping system, but for high-pressure steam mains, it is customary and advisable to use expansion pipe bends made up of full-weight or extra-heavy steel or wrought-iron pipe. When the steam main is of considerable length, it is advisable to divide the expansion between different sections of the piping system, anchor the main rigidly at a point near the middle of each section, and provide an expansion bend in each section. The amount of expansion that can be taken care of by an expansion bend of wrought-iron or steel pipe depends upon the shape of the bend, the mean radius of the bend, the outside diameter of the pipe from which the bend is made, and the amount of straight pipe allowed between the arcs or curved portions of the bend.

EXPANSION BOLT. An expansion bolt is so designed that it can be expanded in a hole in which it is inserted. The expansion may be produced by a screw which enters and expands a split sleeve. Such bolts frequently are used for holding parts to brick, stone, or concrete floors or walls. The expansion part of the bolt enters the hole in the brick, stone or concrete and is then expanded, thus holding the bolt firmly. Expansion bolts are intended especially for "blind holes" in materials which require plain or untapped holes.

EXPANSION, ISOTHERMAL. See Isothermal Expansion and Compression.

EXPANSION JOINTS. In the design of a system of piping, either for power or heating, allowance must be made for the strains due to expansion and contraction. This expansion usually amounts to about $1\frac{1}{2}$ inch per 100 feet of pipe. The expansion and contraction is provided for by the arrangement of the piping, in most cases, but, for long straight pipe lines, expansion joints must be provided. There are three methods commonly used for taking up the expansion in pipes: 1. By using so-called sweep or expansion bends in place of cast-iron elbows, and arranging the piping

so as to provide the maximum amount of flexibility or spring. 2. By the use of swing or swivel joints. 3. By the use of expansion or slip joints.

EXPANSION RATIO. See Ratio of Expansion.

EXPONENT. In mathematics, an exponent is the figure or symbol which indicates the power to which the quantity to which it is affixed is to be raised. In the expression 5^3, the exponent or small figure (^{3}) indicates that 5 is to be raised to the third power; the expression A^n indicates that A is to be raised to the nth power, n being the exponent.

EXPORT TRADE TERMS. See Trade Terms.

EXTENSOMETER. The extensometer is an instrument which may be used in making very careful measurements of elongation, as in determining the elastic limit of materials. With such an instrument it is easy to determine when the load and elongation cease to be proportional. Shortly after this point is reached, the instrument is removed to prevent injury when the specimen breaks.

EXTRACTORS, OIL. See Chip and Oil Separators.

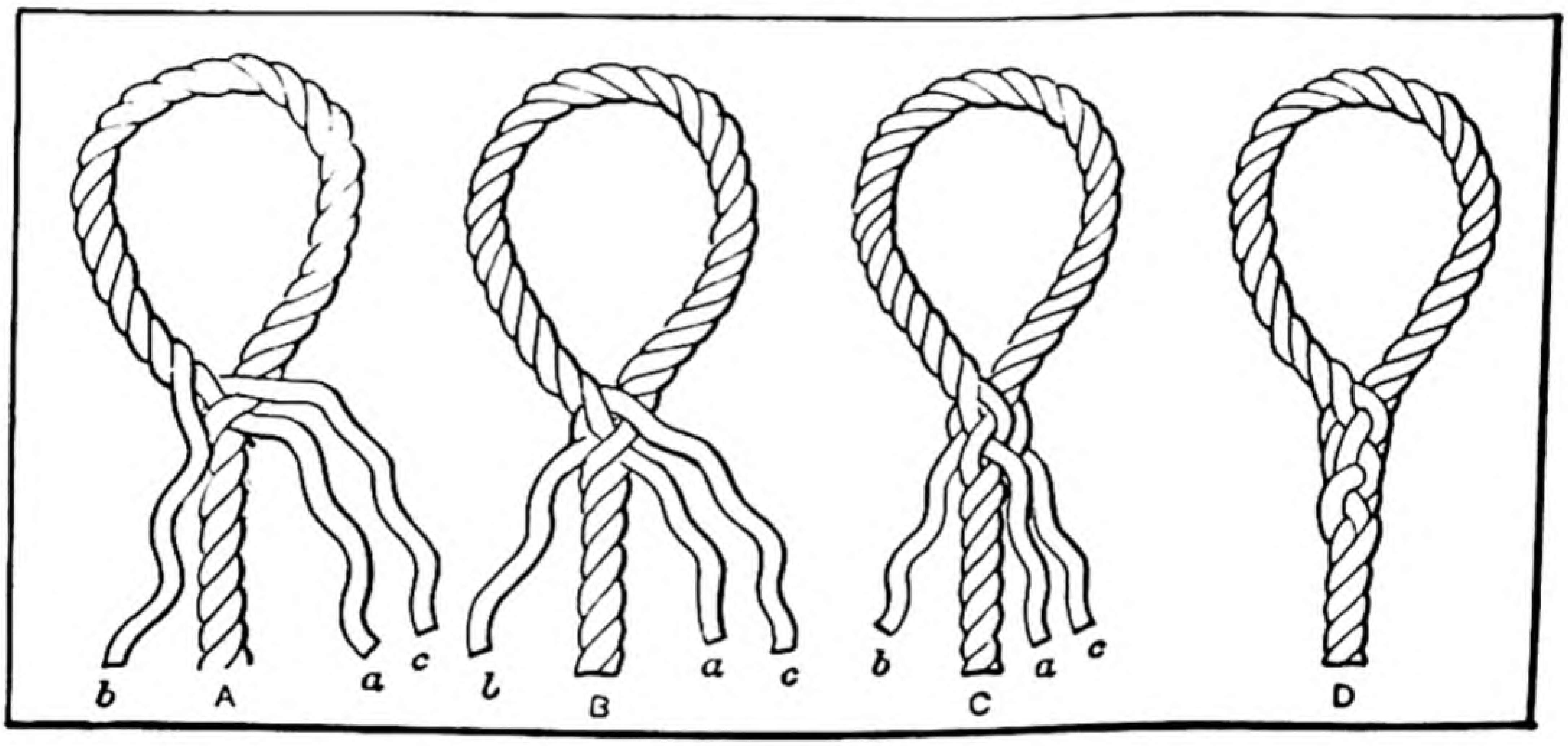
"EXTRA HEAVY." When applied to pipe, the term "extra heavy" means pipe thicker than standard pipe; when applied to valves and fittings, the term indicates goods suitable for a working pressure of 250 pounds per square inch.

EXTRUSION OF METALS. The extrusion process is a method by means of which shapes of fairly plastic metals are produced by forcing the metal, which is usually heated, under high pressure through an aperture of the shape to be produced. In this manner, a continuous bar or pipe of the cross-section of the aperture or die is produced. Lead and tin can be extruded at comparatively low temperatures (250 degrees F.), while copper requires a temperature of about 1750 degrees F. The advantages of the extrusion process are that it permits parts of unusual cross-section to be produced cheaply. On account of the high pressure under which the metal is extruded, its structure becomes more compact and its strength is increased. The surfaces are smooth and free from flaws and other defects. Sometimes metals are extruded at atmospheric temperatures, in which case a higher pressure must be used, but the metal will be more condensed and the grain refined, adding to its strength, hardness, and toughness. It requires, however, five times the pressure to extrude aluminum at 70 degrees F., as compared with the pressure required at 600 degrees F. Small gears, ratchet wheels, racks, padlock hasps, and other special shapes are extruded in long bars which are afterwards sawed up to give the pieces their required thickness. The extrusion process is used

extensively for making collapsible tubes of tin and lead, for containing dentifrice, artists' colors and other preparations. In the extrusion of metals it is natural that lead should have been the one first used, as this is the most plastic of metals. The other metals extruded are aluminum, zinc, copper, and brass, as well as various other alloys.

EYEBOLT. This is a bolt threaded at one end and provided with a loop or eye at the other, so that it may be attached to a ring or hook.

EYE-SPLICE. When a loop is formed at the end of a rope by splicing the free end to the main or standing part of the rope, this is known as an *eye-splice.* The end of the rope is first unlaid about as far as it would be



Method of Making an Eye-splice

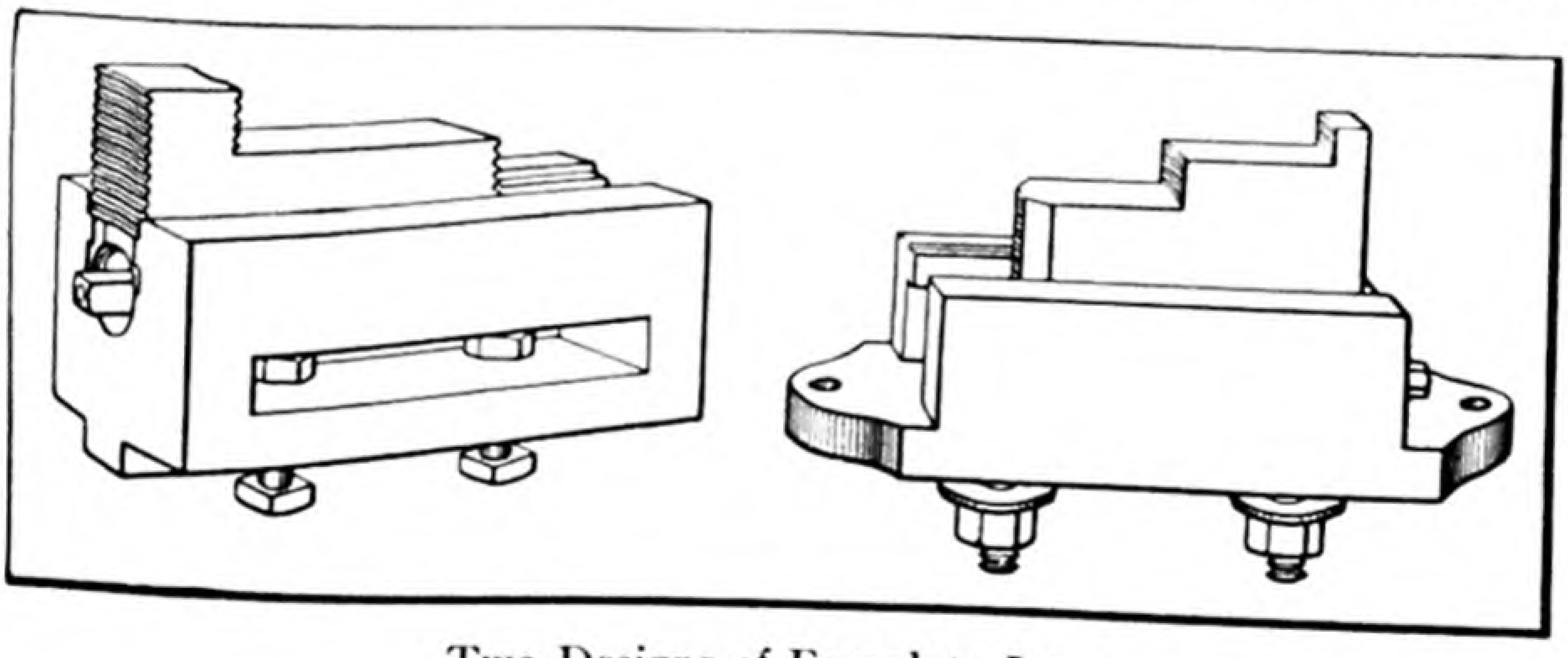
for making a short splice. After bending the end around to form a loop of the required size, the middle strand *a* (see diagram) is tucked under a strand on the main part of the rope, as illustrated at *A*. The strand *b* is next inserted from the rear side under the strand on the main part which is just above the strand under which *a* was inserted. Since strand *b* is pushed under the strand on the main part from the rear side, it will come out at the point where strand *a* went in, as illustrated at *B*. The third strand *c* is now passed over the strand under which strand *a* was inserted, and then under the next successive one, as illustrated at *C*. These three strands are next pulled taut and then about one-third of the fiber should be cut from them; they are next tucked away by passing a strand over its adjoining one and under the next successive strand. The reason for cutting away part of the fiber or yarns is to reduce the size of the splice and give it a neater appearance. By gradually thinning out the fiber, the overlapping strands may be given a gradual taper, as indicated at *D*, which shows the completed eye-splice.

FACE ANGLE OF BEVEL GEAR. There are two methods of designating the face angle of a bevel gear. According to one method, this is the angle between the top of a tooth and a plane perpendicular to the axis of the gear. The term according to the other method means the angle between the top of a tooth and the axis of the gear or one-half the included angle of the blank.

FACE CAM. This is a cam in which a groove for guiding the roller of the cam follower is cut into the flat face of a cylindrical disk. A face cam has an action similar to that of a disk cam, except that the face cam guides the follower positively in both the forward and reverse direction, as the roller engages a slot instead of the periphery of the cam.

FACE MILLING. This term as generally used, means the production of a plane surface by the teeth of a milling cutter which operate in a plane that is at right angles to the axis of the cutter.

FACEPLATE JAWS. Special faceplate jaws (see illustration) may often be used to advantage for holding work on large lathe faceplates, and



Two Designs of Faceplate Jaws

they are also frequently applied to the tables of vertical boring mills. Three or four of these jaws are bolted to a faceplate or a machine table, as the case may be, thus converting it into a kind of independent chuck. Faceplate jaws are held in position by means of square-headed bolts that engage T-slots in the faceplate or table, and they are additionally held and aligned, in most cases, by a tongue that fits into the T-slot.

FACE WIDTH. In spur gearing, the "face" or face width is the length of the teeth or the distance across the gear rim measured parallel to the shaft upon which the gear is mounted. In bevel gearing, the face or face width is the width of the tooth measured on a line parallel to the pitch line.

FACING LATHE. The facing lathe is a special design intended particularly for short work of large diameter. This lathe is designed exclusively for work which is held either in a chuck or on the faceplate, and the tailstock, as well as the screw-cutting mechanism, is omitted. The bed is very short, so that the operator can control the lathe from the end on the faceplate side as well as in front. There are two toolposts on the cross-slide, so that parts may be turned and faced at the same time. Lathes of this class would ordinarily be used for the same general line of work that is done on vertical boring mills.

FACING MATERIALS. Facing materials are applied to the surfaces of foundry molds to improve the appearance of the casting by preventing the fusion of the metal and sand. There are many patent facing materials on the market. Dry plumbago applied with a soft brush is a common facing for green sand work, while a blacking mixture composed of lead, charcoal, and blacking, mixed with clay water, is extensively used for dry sand and loam molds.

FACING SAND. In molding, the sand that is sifted or riddled over a pattern to form the face of the mold is known as *facing sand*. It may be backed up with coarser floor sand. The facing may be of sifted floor sand or of an entirely different grade.

FACTORING. In mathematics, factoring is the process of obtaining the factors of a number or quantity; that is, the numbers or quantities which, when multiplied together, will give as a product the given number or quantity. Thus 3 and 11 are factors of 33 because $3 \times 11 = 33$.

FACTOR OF EVAPORATION. The factor of evaporation is the ratio between the number of heat units required for evaporating one pound of water of a given feed water temperature into steam of a given pressure, to the number of heat units required for evaporating one pound of water from a temperature of 212 degrees F. into steam at atmospheric pressure.

FACTOR OF SAFETY. It is the practice among most engineers engaged in the designing of machinery to base working stresses for given materials and given classes of work, either upon their own experience or upon the observation or successful experience of others, and so long as the quality of the material remains unchanged, and the service does not vary in character, this method is satisfactory. New conditions, for which precedent is lacking, are, however, constantly arising, and materials of different qualities, either better or cheaper, for which the safe working stresses have not been determined, are introduced. The designer is then compelled to determine the proper stress for the work in hand by using a so-called "factor of safety." The name "factor of safety" is misleading,

for several reasons. In the first place, it is not a "factor" from a mathematical point of view, but is, in its use, a divisor, and in its derivation, a product. In order to obtain the safe working stress, the ultimate strength of the material is divided by the factor of safety, and, in order to obtain this factor of safety, several factors, which, in turn, depend upon the qualities of the material and the conditions of service, are multiplied together. If the ultimate strength of a material like machine steel is 60,000 pounds per square inch and it is subjected to a load of 10,000 pounds per square inch, a factor of safety of 6 is used; that is, the ultimate strength of the material is six times as great as the load to which the material is subjected in service.

FAHRENHEIT THERMOMETER. The thermometer that is most commonly used by the English speaking peoples is the *Fahrenheit thermometer* on which the freezing point of water is located at 32 degrees and the boiling point of water (at atmospheric pressure) at 212 degrees. This thermometer scale was probably the first of the three adapted thermometer scales introduced, it having been named after its inventor, a German scientist, who proposed this scale in the early part of the eighteenth century. The Fahrenheit (F.) scale is, as a rule, not used for scientific or electrical work; in that case the centigrade scale is almost exclusively used in all countries.

$$\text{Degrees Centigrade} = \frac{5 \times (\text{degrees F.} - 32)}{9}.$$

FAIRBAIRN CRANE. This is a special type of pillar crane supported and pivoted at the foundation only, in which the column and the boom are built in one piece, generally of a box section formed of angles and plates.

FALLING BODIES. See Gravity.

FAN BLOWER. A fan blower is a special form of ordinary ventilating fan adapted commonly for working pressures up to one pound per square inch, although special types may be constructed for higher pressures. The fan blower is employed principally for forges and cupola furnaces.

FAN BRAKE. A fan brake is a form of absorption dynamometer sometimes used when testing high-speed machinery, such as automobile engines. The fan brake consists of a number of arms keyed to the shaft of the engine, to which flat plates are attached. When such a brake has been properly calibrated, by measuring the power required to revolve it at various speeds, it is very satisfactory. The power absorbed varies as the cube of the speed.

FANS Fans are used for a number of applications in industrial work. Besides their use for heating and ventilation, they are employed for exhausting dust from polishing and grinding rooms, in which case they are generally

connected directly with ducts leading from a hood over the polishing and grinding wheels; they are also used for exhausting shavings from woodworking machinery, and for many similar purposes in various industries. There are two types of fans in common use: (1) the centrifugal fan, often called a "blower," and (2) the disk fan or propeller.

FARAD. The unit of capacity in electricity, as adopted by the International Electrical Congress, in Chicago, 1893, and later made a legal unit for electrical measures in the United States by Act of Congress, July 12, 1894, is the *farad*. This is the capacity of a condenser charged to a potential of one volt by one coulomb of electricity.

FARADAY. See under Electrochemical Equivalent.

FARMER'S DRILL. A straight-fluted form of drill. See under Drills the paragraph on Straight-fluted Drills.

FATHOM. A length measure; 1 fathom = 2 yards = 6 feet = 1.8288 meter.

FATIGUE STRESSES. So-called "fatigue ruptures" occur in parts that are subjected to continually repeated shocks or stresses of small magnitude. Machine parts that are subjected to continual stresses in varying directions, or to repeated shocks, even if of comparatively small magnitude may fail ultimately if designed, from a mere knowledge of the behavior of the material under a steady stress, such as is imposed upon it by ordinary tensile stress testing machines. Examinations of numerous cases of machine parts, broken under actual working conditions, indicate that at least 80 per cent of these ruptures are caused by fatigue stresses. Most fatigue ruptures are caused by bending stresses, and frequently by a revolving bending stress. Hence, to test materials for this class of stress, the tests should be made to stress the material in a manner similar to that in which it will be stressed under actual working conditions.

FATIGUE TESTING MACHINE. One make of fatigue testing machine designed to record the number of alternations of stress that may be applied to a steel specimen before destruction is accomplished, consists of a baseplate provided with a housing in which are mounted ball bearings that carry the specimen in a horizontal plane, and another housing with ball bearings and a shaft on which a pulley is mounted to drive the equipment from a motor. There are also two ball bearings which are put on the specimen to carry the weights that apply the load or stress. Hook-bars are attached to the weight bearing housings. All the ball bearings are provided with easily adjustable compensating chucks to fit the specimen, so it is a simple matter to mount the specimen in the machine. A bracket at one end of the machine carries a revolution counter which records the

number of revolutions made by the specimen under test up to the time of failure. The specimen is connected to this counter by means of a flat notched bar which falls out of position when failure occurs and causes the counter to stop. At the same time the broken specimen swings out of contact with the driving shaft.

FAURE PLATE. This is a type of electrode for lead batteries, also known as "pasted" plate, in which the active material in the form of lead oxide and sponge lead is applied mechanically to a lead body. After this the plate is subjected to a forming process.

FEATHER. See Spline.

FEATHEREDGE FILES. Files of this type taper in cross-section from the center toward each edge. They are of blunt form, double-cut, bastard, second-cut, or smooth. This shape is seldom called for, as the knife file is generally used instead.

FEED MECHANISMS. The term "feed mechanism" or "feeding mechanism" as applied to machine tools or other classes of manufacturing equipment, usually relates to some form of mechanism (1) for feeding either a cutting tool or the work as in turning, planing, drilling or milling, and generally for providing also means of varying the rate of tool or work movement per revolution or stroke; (2) a mechanism for feeding raw material or parts from some source of supply to the working or operating position. A feed mechanism which is designed to control primarily the rate of tool or work-feeding movement usually consists of a train of gearing with provision for changing the ratio between the driving and driven members. Feed mechanisms of the type for feeding stock or parts are made in a great variety of types and designs, depending upon the nature of the work.

Many machines which operate on large numbers of duplicate parts which are separate or in the form of individual pieces are often equipped with a mechanism for automatically transferring the parts from a magazine or other retaining device, to the tools that perform the necessary operations. The magazine used in conjunction with mechanisms of this kind is arranged for holding enough parts to supply the machine for a certain period, and it is equipped with a mechanical device for removing the parts separately from the magazine and placing them in the correct position wherever the operations are to be performed. The magazine may be in the form of a hopper, or the supply of parts to be operated upon by the machine may be held in some other way. The transfer of the parts from the hopper or main source of supply to the operating tools may be through a chute or passageway leading directly to the tools, or it may be necessary to convey the parts to the tools by an auxiliary transferring mechanism which acts in unison with the magazine feeding attachment. These automatic feeding

mechanisms are usually designed especially for handling a certain product, although some types are capable of application to a limited range of work.

FEED MECHANISMS, POWER PRESS. See Power Press Feed Mechanisms.

FEED PUMPS. See Boiler Feed Pump; also Centrifugal Feed Pumps.

FEED-WATER, BOILER. See Boiler Feed-water Hardness; Boiler Feed-water Heater; Boiler Feed-water Impurities; Boiler Feed-water Oil Test; Boiler Feed-water Purification.

FELLOWS STUB-TOOTH GEARS. See Stub-tooth Gears.

FERRITE. If a piece of iron or steel is placed under the microscope, it will be found that the metal is not absolutely homogeneous, but consists of various constituents slightly different in color and forming a surface similar to that of a granite rock. Just as granite shows distinct crystalline grains of different minerals, so iron or steel consists of a mixture of microscopic particles. When having slowly cooled, for example, it consists of an iron carbide, known as *cementite*, and of *ferrite*, which is pure, or nearly pure, metallic iron. Ferrite is a soft and weak constituent with high electric conductivity, and, in many respects, like copper, except in its color. When carbon is present in iron to any great extent, ferrite is transformed into cementite, which latter constituent is harder than glass and nearly as brittle; hence, if one per cent of carbon is present in the iron, 15 per cent of the soft ferrite is replaced by cementite. This is one of the reasons why even a small addition of carbon in steel changes its mechanical properties to so great a degree. See also Steel Under the Microscope.

FERRO-MANGANESE. Ferro-manganese is an alloy of manganese and iron, containing generally about 80 per cent of manganese, 15 per cent of iron, and 5 per cent of carbon, with small percentages of silicon and other impurities. Ferro-manganese is used for recarburizing when making steel by the Bessemer and open-hearth processes.

FERROUS ALLOYS. Ferrous alloys differ from non-ferrous alloys in that they contain iron. Steel and cast iron are outstanding examples of ferrous alloys, whereas in the non-ferrous group there are the various brass, bronze, aluminum and other alloys.

FETTLING. In copper reverberatory furnace operation, silicious ores are continuously dropped through the roof and contiguous side walls of the furnace so as to form a false wall of silicious metal inside of the furnace to prevent the slag and charge from attacking the furnace walls. This charging operation is known as "fettling," "fixing," or "charging."

FIBER. This is the general name used for a number of structural components of animal and vegetable tissue utilized in the industries. According to the source of the raw material, there are a number of classes of fiber, such as wood fiber, horn fiber, asbestos fiber, etc. Fiber is used for gearing, for friction wheels, as an electric insulating material, and for various other purposes.

FIBER BENDING AND FORMING. Fiber should always be bent parallel to the grain (the long way of the sheet), because it is difficult to bend fiber across the grain without breaking it. The general practice is to soften the material (more or less) by immersing it in hot or cold water until sufficiently tempered, and then drying it in heated forms under enough pressure to keep the shape desired. The fiber should be left in the heated forms long enough so that it will retain the desired shape after cooling. However, heated forms are not always necessary. If the material can be steamed, instead of immersed, it will require less time to set. Angles can be bent in bending brakes fitted with electric gas, or steam heat. Special pieces can be formed on a hot plate in cast-iron forms, under pressure of a hand-operated spring plunger. In making up the top and bottom forms, some allowance should be made for the fact that fiber swells slightly when it is soaked or steamed. Tubes can be bent by softening in hot water, filling with sand, and clamping in wooden or metal forms, after which it is necessary to dry them at about 150 degrees F.

FIBER PUNCHING. Fiber can be easily blanked, pierced, and shaved on ordinary punch presses. For blanking and piercing thin material, the punch should be a neat fit in the die, while for stock $\frac{1}{4}$ inch thick, a difference of about 0.008 inch will give the best results. When a rough edge is not objectionable, fiber can be blanked out up to $\frac{1}{4}$ inch thick. When heavier stock is blanked, it is likely to " check in " too far and cause considerable wastage, although some material up to $\frac{7}{16}$ inch in thickness can be blanked. Smooth edges can be obtained by forcing blanked or sawed fiber blocks through a hollow shaving cutter of the desired shape. The edges of the cutter should have a slant of about 45 degrees. Sharper angles will often give smoother edges, but the cutter will not last as long. A better finish can be had by using a roughing and a finishing cutter. It is generally necessary to allow from $\frac{1}{16}$ to $\frac{1}{8}$ inch all around for shaving, according to the shape of the pieces. When trouble is encountered by checking of the stock while blanking or shaving, softening the fiber by heating will often overcome the difficulty. Dies and cutters for fiber can be made without any clearance for $\frac{1}{2}$ inch or more below the cutting edge. The bottom of the die may be counterbored within $\frac{1}{2}$ or $\frac{3}{4}$ inch of the top to facilitate machining. Such a die will not change its size in grinding and will give

better results than a die with clearance to the cutting edge. If the cutting edge of a shaving cutter is mouthed out very slightly with a fine oilstone, the stock will bind slightly in passing through, which will tend to polish the edges smoothly.

FIELD SWITCHES. Field switches are especially designed to open or change the connections of the field of a motor or generator. There are three varieties of field switches; namely, the plain field switch, the bus and self-exciting field switch, and the field break-up switch.

FILE CLEANING. A piece of copper is fairly good for cleaning files but sheet-fiber is much better. A disk of fiber mounted upon an ordinary emery wheel stand is very effective. When the file to be cleaned is held against this revolving disk or fiber it will be cleaned much quicker and better than would be possible by hand or by the copper method. Fiber $\frac{1}{4}$ inch thick is best suited for this purpose.

FILE HISTORY. One of the earliest implements for filing, to which reference can be found, appear to have been made from the skins of certain fish, and even today in Great Britain old-fashioned wood carvers use the skins of the dog fish to smooth their work. *Bronze files* were in use when this metal was the general material for tools and implements, and there is evidence in the Bible that different shapes of files were in use about three thousand years ago. Several specimens of ancient bronze files are still in existence. One of these, believed to be about 3500 years old, was dug up in Crete. This file has a rounded back, as well as a flat surface, bearing an astonishing resemblance to the half-round file of today. It is about $3\frac{5}{8}$ inches long, $\frac{3}{8}$ inch wide, and $\frac{1}{4}$ inch thick.

One of the earliest examples of *iron files* was found on the site of the Swiss lake dwellings, and dates from the time when Europe was the home of a race far more ancient than any of which we have any permanent records. This file has coarse teeth running across the blade at right angles to the sides and has a well developed tang, much like that of modern files. Another ancient iron file forms part of the collection of tools left at Thebes in Egypt by Assyrian invaders. This file is believed to date from about the seventh century B. C. Files have been found on the sites of the old Roman camps in England.

Specific references to files were made by Daimachus, a Greek writer in the time of Alexander the Great, about 300 years B. C. This writer enumerates four kinds of steel, describing their uses. From one kind were made files, augers, chisels, and implements for cutting stone. *Steel files* have been used for several centuries, and in an eighteenth century French encyclopedia there are a number of illustrations of files which differ in few respects from the modern tool. Formerly all files were cut by hand,

but now practically all files are machine-cut. Although the machine-cutting of files is a comparatively recent development, the idea of machine-cutting is by no means new. Raoul, a Frenchman, cut files by machinery in the eighteenth century, and in 1836 a file-cutting machine patented by Captain John Ericsson was used in England. Machine-cut files are made with as many as 180 teeth to the inch, the cuts being scarcely discernible to the eye.

FILE SHAPES. See name of file, such as Cant-file; Circular File; Flat File; Half-round Files; Rotary Files; Round Files, etc.

FILE TEETH. A *single-cut* file or "float," as the coarser cuts are sometimes called, has single rows of parallel teeth extending across the face at an angle of from 65 to 85 degrees with the axis of the file. This angle depends upon the form of the file and the nature of the work it is intended for. A *double-cut* file has two rows of teeth crossing each other. The angle of the first row is, for general work, from 40 to 45 degrees, and the second row, from 70 to 80 degrees. *Rasp* teeth are round on top and disconnected, being formed by raising, with a punch, small portions of stock from the surface of the blank.

Single- and double-cut files are further classified according to the spacing of the teeth. The names commonly used to designate the different grades of cut are "rough," "coarse," "bastard," "second-cut," "smooth," "dead-smooth," or "super-smooth." "Rough" files are usually single-cut, and the "dead-smooth," double-cut. The other grades are made in both double- and single-cuts. Degrees of coarseness are only comparable when files of the same length are considered, the number of teeth per inch of length decreasing as the length or size of the file increases. Some makers use a series of numbers to designate the cut or coarseness instead of names.

FILE TEETH, CUTTING. There are three general methods of cutting the teeth of files: 1. By hand (using a hammer and chisel). 2. By means of special file-cutting machines of the mechanically-operated chisel type. 3. By etching with a mechanically guided tool. While the hand method is comparatively slow and expensive, skillful workmen are able to produce excellent files, although practically all files now used are cut by machines. These machines have been developed so that they not only enable the work to be done efficiently but produce files which are more accurate and effective than those cut by hand.

The *hand method* to be described has been practiced by the hand file-cutters in Sheffield and Lancashire for a century. The large file blanks are ground, and the smaller ones filed to shape, and slightly greased before cutting. The cutter sits before a square stake on which the blank is laid with the tang toward him and the two ends held down by two leather loops

which are pressed down by the right foot. Cutting is begun at the point and is done by a very short chisel, the edge of which is slightly blunted to indent rather than cut the steel. To cut opposite faces of a file the face first cut is laid upon a plate of pewter; triangular and round files are laid in corresponding grooves in blocks of lead.

A *file-cutting machine* is designed to strike a series of rapid blows with a suitably formed chisel, for producing tooth grooves of any desired depth in a file blank which is fed automatically past the chisel at such a rate as to give the desired spacing of the teeth. The chisel head or hammer of a file-cutting machine weighs, complete, from 8 to 12 pounds, and ordinarily makes from 2000 to 3000 strokes per minute, although the number of strokes may vary from 500 to 3500 per minute, the speed of cutting depending upon the weight of the file being cut. The first known record of a file-cutting machine is a design made by Leonardo da Vinci, the well-known Italian genius, about 1500.

Large quantities of files are not cut by means of a mechanically-operated chisel but by a grooving process that is known as *etching*. This process is entirely different from that of cutting by means of a chisel and produces a higher grade of file. When forming the teeth by etching, the file is laid in a holder where it is steadied and guided by the workman's left hand. With his right hand he operates the etching tool, which is attached to a swinging framework. The etching tool is simply swept back and forth across the work at the proper angle and with the proper degree of pressure, the latter being controlled by the foot of the operator which bears down upon a stirrup which hangs from the handle of the etching tool. This pressure must be varied to suit conditions, such as hard spots in the blanks or the necessity of cutting deeper at one point than at another. The shape of the file is what determines whether a blank should be etched or cut with a chisel. A flat surface should not be etched nor is there any need for it. On round surfaces, however, particularly where it is necessary to preserve accurately the outline of the blank, etching is preferable to cutting. A satisfactory machine has been developed for etching the first teeth of a double-cut file.

FILE TEETH, RESHARPENING. There are several processes for resharpening files by the use of acid solutions. The acid must not be permitted to attack the files unduly. To prevent this, it is advisable to make a few tests or trials to determine the length of time the files should be immersed in order to obtain the desired results, before proceeding with the work on a quantity basis.

Cleaning Solution. — First clean the files by immersing them in a solution of caustic soda and boiling water for a period of from ten to fifteen minutes. This solution is made by dissolving 100 grains of caustic soda in one gallon

of water. The same proportions should be used if a larger quantity of the solution is required. Two gallons will ordinarily be sufficient for cleaning 100 files of the sizes generally employed in the shop.

Use of Nitric and Sulphuric Acids. — After the cleansing treatment, the files are placed in an acid bath. This bath is made by adding twelve parts of water (by volume) to a solution consisting of one part nitric acid, one part fuming (Nordhausen) sulphuric acid, and one-third part concentrated sulphuric acid. These parts are measured by volume and not by weight. The files, when placed in the acid solution, should not overlap and should be arranged so that the solution will reach all surfaces. It is preferable first to suspend the files in the tank and then add the acid solution. The files should be allowed to remain in the solution from five to ten minutes, the exact time being determined by experiment.

Sulphuric-acid Process. — Experience in sharpening between 2000 and 3000 files in acid solutions indicates that the following method gives good results. The first step is to remove all grease and dirt from the files. This may be done by soaking the files a few hours in gasoline and then brushing them with a wire brush, or by boiling them a few minutes in a 10 or 15 per cent water solution of caustic soda, and then drying and brushing them. It is essential that the files be thoroughly cleaned, as the acid cannot reach the steel through grease or oil. The clean files are placed in an enamel basin, a lead-lined box, or a "Pyrex" glass baking dish. Short pieces of wire or nails are placed between the files to separate them sufficiently to permit the acid to reach all the surfaces that are to be sharpened.

After covering the files with water, sulphuric acid is slowly poured into the tank until a solution that is about 25 per cent acid is obtained. As the acid combines with the water, a considerable amount of heat is generated which causes the acid to act more rapidly. Files having fine teeth may be sharpened in from three to five minutes, while files with coarse teeth generally require from five to twenty minutes. A second batch of files can be treated in the same solution by adding a little sulphuric acid. After two or three batches of files have been treated, however, it is usually necessary either to heat the solution or make a new one.

Nitric and Hydrochloric Acids. — Another process consists of immersing the files in a warm aqueous solution of nitric acid and hydrochloric acid, consisting preferably of about equal parts of the acids and of water. This solution should be kept at a constant temperature. After the files have been treated with the acid solution, they should be washed in lime water or some other alkaline solution, and then wiped with oil.

Adding Acid to Water. — Caution must be exercised in mixing sulphuric acid and water. Always pour the acid into the water slowly; never pour

water on the acid, as an explosion may result, the same as when babbitt is poured into a wet box or mold. In both cases the explosion is caused by the sudden generation of steam. Commercial hydrochloric acid diluted with about 10 per cent water and heated to near the boiling point can be used instead of sulphuric-acid solution. The diluted hydrochloric acid has the advantage of being safer to handle.

As soon as the files are removed from the acid solution, they are washed in running water and dried rapidly by heating. After drying, they may be dipped in gasoline containing about 5 per cent paraffin or engine oil. The gasoline evaporates, leaving a thin coat of oil on the files.

FILE TERMS. The *length* of a file means the distance from the point to the heel and does not include the tang. The *heel* is that end of the file body adjacent to the handle. A *blunt file* is one having the same sectional shape from the point to the tang. The coarse grades of single-cut files are sometimes called *floats*. *Safe-edge* means that the edge or side is smooth and without teeth, and may be presented to a surface that does not require filing. *Over-cut* is a term used to describe the first series of teeth on a double-cut file. *Up-cut* means the series of teeth superimposed on the over-cut series of a double-cut file. *Re-cut* means the working over of old worn-out files by annealing, grinding out the old teeth, re-cutting, hardening, etc. Re-cutting is seldom practiced at the present time. The term *superfine* (or super) cut is used by Lancashire file-makers to designate the grade of cut known in the United States as "dead-smooth." *Taper* is used to distinguish a file having tapering sides from one that is blunt or straight. A file is tapered when it is thinner at the point than at the middle, and is full-tapered when thinner at the point and the heel than at the middle. Custom has also established the use of the term "taper" as a short name for "three-square" or triangular handsaw files.

FILE TESTING. The quality of files can be tested by a special machine which records the endurance and capacity for removing metal, by producing a curve or diagram on sectioned paper wound about a cylindrical drum connected with the file reciprocating mechanism, so as to make one revolution to 120,000 strokes of the file. On these diagrams, the horizontal distances represent the number of strokes made by the file being tested and the vertical distances, the number of cubic inches of metal removed. Tests show a remarkable difference in the quality of files, some being worn out after removing less than one cubic inch of iron, and cutting at the rate of only one cubic inch per 10,000 strokes; whereas, files of good quality remove $12\frac{1}{2}$ cubic inches and cut at the rate of 5 cubic inches per 10,000 strokes.

It has been estimated that the useful life of a file is, on an average, 25,000 strokes, which is equivalent to two full working days of ten hours each.

FILLETS. Fillets are concave moldings used in patternmaking to fill in the sharp corners formed by surfaces lying in planes at an angle to each other. They are very important in making machinery castings as the strength of the cast piece is greatly increased by their use, and its liability to fracture is greatly lessened. Fillets are either " stuck " or " planted." A stuck fillet is one that is worked from the solid, and a planted fillet is one made separately and applied. Planted fillets, which are the ones commonly used, are made of wood, leather, beeswax, putty, and other plastic materials. Metal fillets have also been used to some extent, but are not very popular, as they are hard to fasten and soon work loose.

Wood fillets are made by the patternmaker with a round sole plane and are used where corner radii of 1 inch and over are required. *Leather fillets* are in general use for filleting of 1-inch radius or less, and may be worked into any corner whether the angle be acute or obtuse. They are usually worked in place with a spherical-ended tool. Owing to their pliability, leather fillets can be used either on straight work or regular and irregular curves. *Beeswax* and other plastic materials are quite commonly used for fillets of small radii.

FILTERS. River water often contains the discharge from sewers, fine sand, or other fine particles which will readily pass through the finest strainer and also float in still water. In cases of this kind, some form of filter is necessary for boiler feed water. Such filters are usually composed of crushed quartz, coke or charcoal, excelsior, burlap, or other porous material which will pack closely and present a rough surface to which the particles of solid material will readily adhere. There are many forms of filters in use, one of the simplest consists of a wooden tank having three compartments. The main compartment has a perforated bottom which supports a bed of coke. The water enters at one end near the top and passes through the filter into a compartment below. The water then passes into a third compartment at the opposite side of the filter from which the water enters, and from here it is drawn out by a pump. Particles of coke or sand which may be carried through the filter will collect in the bottom of the second chamber. In another form, known as a *pressure filter*, the filtering material is sharp sand, machine-crushed and sifted quartz or the like. In general the feed water enters at the top, passes downward through a comparatively deep filter bed and out through a pipe which is connected with a system of strainers. The filtering material is broken up and cleansed by means of a steel agitator driven by a worm-gear at the top.

FINISHED SURFACE INSPECTION. Very slight cracks in ground surfaces that cannot be seen even with a microscope can be discovered by magnetizing the part and immersing it in a solution of kerosene oil having

very fine iron dust suspended in it. A magnetic field immediately surrounds the crack and the fine iron particles adhere in a peculiar shape to the hardened surface where the surface crack appears. This method of inspection has to do only with the quality of the surface, but not directly with the actual degree of finish.

FINISHED SURFACE STANDARDIZATION. A positive indication of "degree of finish," can be obtained since the reflection of a finished surface can be taken as a measure of its surface finish. To do this, a photo-electric cell is connected in a suitable amplifying circuit to a milliammeter; the ratio of the values read on the scale of the milliammeter gives very accurately the degree of the polish or finish on the surface of the sample being tested. The sample is exposed to a source of light, and the light is reflected against the photo-electric cell. After some standard has been adopted which may be called the unit of finish, the finish on the parts compared with it can be read off mechanically from the deflection of the needle on the scale of the milliammeter.

FIN OF DROP-FORGING. On a drop-forging the fin is the excess metal that is forced out of the die impression into the space between the upper and lower die sections. See Flash of Drop-forging Die.

FIN OF ROLLED SECTION. In rolling mill practice a fin is a projection extending from the side of rolled sections. Such a fin causes considerable trouble and not infrequently the rejection of the finished product, as the fin formed when the bar or shape passes through one pass is likely to be rolled back into the bar at the next pass.

FIREBRICK PROPERTIES. Brick intended for use in furnaces, flues, and cupolas, where the brickwork is subjected to very high temperatures, is generally known as "firebrick." There are several classes of firebrick, such as fireclay brick, silica brick, bauxite brick, chrome brick, and magnesia brick. Ordinary firebricks are made from fireclay; that is, clays which will stand a high temperature without fusion, excessive shrinkage, or warping. There is no fixed standard of refractoriness for fireclay, but, as a general rule, no clay is classed as a fireclay that fuses below 2900 degrees F. Fireclays vary in composition, but they all contain high percentages of alumina and silica, and only small percentages of such constituents as oxide of iron, magnesia, lime, soda, and potash. A great number of different kinds of firebrick are manufactured to meet the various conditions to which firebricks are subjected. Different classes of bricks are required to withstand different temperatures, as well as the corrosive action of gases, the chemical action of furnace charges, etc. The most common firebrick will melt at a temperature ranging from 2830 to 3140 degrees F.; bauxite brick, from 2950

to 3245 degrees F.; silica brick, from 3090 to 3100 degrees F.; chromite brick, at 3720 degrees F.; and magnesia brick, at 4950 degrees F.

FIRE CRACKS. In brass and other alloys, so-called fire cracks are defects due to molecular changes produced by mechanical deformation, which appear during the annealing process. German silver is particularly liable to this defect.

FIRE HOSE COUPLINGS. See Hose Couplings.

FIRE POINT OF OIL. The fire point or fire test of an oil is the temperature at which the oil will catch fire and continue to burn. The fire point and the flash point are two important properties in oil, particularly when the oil is used under conditions where it may be exposed to high degrees of temperature, as, for example, in hardening rooms or electric transformers. To make a flash point of fire test, proceed as follows: Place a quantity of oil in an open vessel. Heat it slowly and uniformly and note the temperature by a thermometer immersed in the oil. From time to time, let a small flame impinge upon the surface of the oil; the lowest temperature at which a slight explosion or flash takes place is the *flash point.* Continue this test until the oil will be set afire by the explosion or flash. The temperature when the oil will ignite and burn continuously should be noted on the thermometer. This temperature is the fire point. See Flash Point of Oil.

FIRE-TUBE BOILER. A steam boiler, so designed that the hot gases from the boiler furnace pass through tubes which are enclosed in a shell and surrounded with water, is known as a fire-tube boiler. Fire-tube boilers are generally of the externally-fired type and mostly horizontal. Marine and locomotive boilers and certain other types of internally-fired boilers have fire tubes.

FITCHBURG PLAN. This is a system of apprenticeship education in which an arrangement is made between the public high schools and manufacturers, according to which the apprentices spend alternate weeks in the shop and in the school. It is known as the " Fitchburg plan of apprenticeship education " because it was first applied in Fitchburg, Mass. This plan is also called " cooperative apprenticeship."

FITS, MACHINE. See Driving Fits; Forced Fits; Shrinkage Fits.

FITTINGS. The term " fittings " as applied to pipe work, includes the various parts used in pipe lines for connecting different pipes, *viz.*, ells or elbows, tees, and crosses, as well as pipe flanges. They are made from cast iron, wrought iron, malleable iron, or composition metal. See Pipe Fittings.

FIXED-WHEEL GRINDING. By the fixed-wheel method of grinding, the grinding wheel is fed in at once to the correct depth determined by a previously set stop, instead of feeding the wheel in at each traverse. Two traverses are made over the work, one being a roughing cut and the other a finishing. Parts are also ground by leaving the wheel slide "fixed," that is, instead of feeding the wheel in on the work each time a new piece is put between the centers, the wheel slide is not adjusted until truing of the wheel has reduced its diameter, necessitating resetting.

The fixed-wheel method is highly productive on classes of work for which it is adapted, but it could not be used with any degree of success on extremely long slender shafts because of the liability of chatter and springing of the work, even if the latter were rigidly supported by steadyrests. It also has a tendency to wear the wheel down rapidly, and difficulty is sometimes experienced in obtaining a wheel that will not clog or glaze but be hard enough to grind several pieces without retruing or resetting of the wheel slide. This method is particularly adapted to the grinding of bronze and cast-iron bushings, and work of a similar character. As far as the allowance for grinding is concerned, less metal is left on the diameter of the work to be removed by the grinding wheel, when the fixed-wheel method of grinding is used, than when the regular traverse method is employed.

FIXTURES. Fixtures may be defined as special devices, used in the manufacture of duplicate parts of machines, or manufactured devices in general, intended to make possible interchangeable work at a reduced cost, as compared with the cost of producing each part individually. The piece of work to be machined is held and properly located in the fixture, the fixture, in turn, being held on the table of the machine on which the operation is to be performed. The terms "jig" and "fixture" are frequently used interchangeably, but, as a general rule, a jig is a tool which, while it holds the work, at the same time also contains guides for the respective tools to be used (for example, a *drill jig*), while a fixture only holds the work while the cutting tools are performing the operation upon the piece, without containing any special arrangements for guiding the tools. The fixture, therefore, must itself be securely held or fixed to the machine on which the operation is performed; hence, the name. Fixtures are mainly used on milling machines, planers, boring mills, and lathes.

FIXTURE THREAD. See Electric Fixture Thread; also Pipe Thread for Fixtures.

FLAME, NEUTRAL. See Neutral Flame.

FLANGE STEEL. So-called "flange steel," which is generally used for the heads of steam boilers, is an especially tough and ductile quality

of open-hearth steel. The A. S. M. E. boiler code specifications for flange steel are as follows: Manganese, 0.30 to 0.60 per cent; phosphorus, acid, not over 0.05 per cent; phosphorus, basic, not over 0.04 per cent; sulphur, not over 0.05 per cent. An analysis is to be made by the manufacturer from a test ingot taken during the pouring of each melt, and a copy given to the purchaser or his representative.

FLAPPING. The operation of agitating a molten copper bath by a rabble, for the removal of some of the impurities by oxidation, is called flapping.

FLASH-BACK CHAMBER. A flash-back chamber is a compartment in certain types of acetylene generators which is filled with water and serves the double purpose of washing the gas and forming a water seal between the service pipe and the acetylene in the generator.

FLASHING. A process by means of which the fin is removed from a ball blank in the manufacture of steel balls is known as flashing. The machine in which the flashing is done is generally termed a *rotary file*. Large balls are "flashed" separately in a special fixture by a grinding wheel.

FLASH POINT OF OIL. In specifying oil for various purposes, a flash point and a fire point are often specified. If oil is heated slowly, it will vaporize, forming an inflammable and explosive mixture with the air over the surface of the oil, and at a certain temperature it will be found that this vapor will flash up, if ignited, but the main body of the oil will not ignite. On further heating, a temperature is reached when the production of vapor is rapid enough to maintain a continuous flame, and then the body of the oil catches fire and burns. The *flash point* is the lowest temperature at which the vapor will flash up without setting the oil on fire; the *fire point* is the lowest temperature at which the oil will burn. In some oils these points come so near together that it is impossible to distinguish between them, while in other oils they may be 20 degrees or more apart. The flash point is not an indication of the value of an oil for any particular purpose. It is simply an indication of the temperature at which the oil gives off vapors in such proportion that they form an inflammable mixture with the air. The flash points of mineral lubricating oils vary, with few exceptions, from 300 to 600 degrees F. The flash point can be considerably exceeded if the oil is protected by steam.

FLASKS FOR MOLDING. Flasks or molding boxes confine the sand used in making all molds that are not formed in the floor. They may be of wood or iron and in shapes or sizes to suit the work. The iron flasks are superior, as there is less likelihood of straining the mold in handling it, and the smaller sizes are made interchangeable, the pins and holes of a

given size flask being the same. *Snap flasks* are hinged at one corner or side and are held together with a snap fastener at the opposite corner. This type of flask confines the sand while the mold is being made, but may be removed as soon as the mold is finished, so that it can be used again before the mold is poured. Snap flasks are used for light work and are usually square, rectangular, or round.

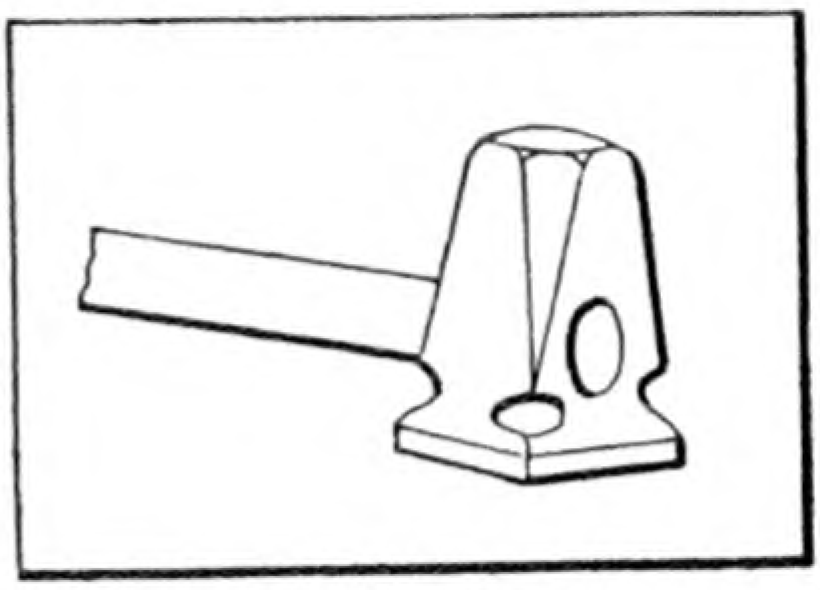
FLAT FILE. A flat file is parallel in both longitudinal sections, from the heel to the middle, and tapered in both sections from the middle to the point, the thickness of the point being about two-thirds and the width about one-half that of the stock from which the file is made. The flat file is one of the most common files in use and is not confined to any specific class of work, but is employed for a great variety of purposes. Ordinarily, the teeth are double-cut, and either bastard, second-cut, or smooth. A single-cut flat file is preferred for some classes of work.

FLAT KEY. A flat key differs from a saddle key in that it bears against a flat surface on the shaft. The key is not sunk into the shaft but it gives it a fairly good grip. This type is not adapted to heavy work, however, owing to the excessive strains to which the hub is subjected, as the shaft tends to turn.

FLAT ROPE. The type of wire rope that is made in the form of a band or ribbon and that has been likened to a watch spring, because it will wind upon itself in a very narrow space, is known as "flat rope." It is composed of a number of wire ropes known as "flat-rope strands" placed side by side and then sewed together with soft iron wire. The sewing or filling wires are of a much softer material than the steel wires composing the strands of the rope, and, therefore, act as cushions for the strands. Flat ropes are used principally for hoisting purposes. When round ropes are used for hoisting heavy loads from deep shafts, very large and heavy drums are required on which to wind the rope, but the flat rope, winding on itself, needs a reel only a little wider than the rope itself. In addition, the flat rope has the advantage that it does not spin or rotate the load in the shaft. Such ropes are made, at the present time, in sizes ranging from $1\frac{3}{4}$ to 8 inches in width, from $\frac{1}{4}$ to $\frac{7}{8}$ inch in thickness, and up to 3000 feet in length.

FLATTENING TEST. This term as applied to tubing refers to a method of testing *tubing* by hammering it flat until the inside walls are parallel and separated by a given distance — usually equal to three times the wall thickness. Boiler tubes subjected to this test should show no cracks or flaws. The flattening test applied to *rivets*, consists in flattening a rivet head while hot to a diameter equal to $2\frac{1}{2}$ times the diameter of the shank or body of the rivet. Good rivet steel must not crack at the edges of the flattened head.

FLATTERS. The tools used by blacksmiths for finishing the flat surfaces of forgings are called *flatters* and *sets*. Flatters are generally made from $2\frac{1}{4}$ to $2\frac{3}{4}$ inches square on the face, which should be slightly crowning in the center and the edges well rounded off to prevent their leaving sharp marks upon the work. Sets are of various shapes and sizes, but all are modeled more or less on the same principle as flatters and are used for similar work. It is of advantage to use a flatter with its edges well rounded for fillets, and one with sharp square edges to finish corners which must be sharp.



Blacksmith's Flatter

FLAT TONGS. This is a type of tongs used by blacksmiths. These tongs usually have a small longitudinal V-shaped depression the full length of the flat jaws, so that they can be used to hold round stock or square stock cornerwise.

FLAT TURRET LATHE. The flat turret lathe is so named because the turret is a flat circular plate mounted on a low carriage to secure direct and rigid support for the tools, from the lathe bed. The tools, instead of being held by shanks inserted in holes in the turret, are clamped firmly onto the low circular turret plate so that they do not overhang, but have an unyielding support directly below the cutting tools. This type of turret lathe was introduced in 1891, and was designed by James Hartness. Lathes of the flat-turret class are sometimes referred to as *turntable lathes*.

FLAT TURRET LATHE, DOUBLE-SPINDLE. The double-spindle design of turret lathe has two parallel spindles the axes of which are in a horizontal plane, and a large flat turret which holds a double set of tools, so that two duplicate castings or forgings can be turned at the same time. This type was designed primarily for chuck work and can be used as a single-spindle machine if desired. The double-spindle type is recommended when work is to be produced in such quantities that the increase in time for a double set-up becomes a secondary consideration.

FLEMISH FINISH ON BRASS. The so-called Flemish finish can be given to brass with a solution composed of $\frac{1}{4}$ ounce of sulphuret of potassium; from 1 to 2 ounces of white arsenic; 1 quart of muriatic acid; and 10 gallons of water. The arsenic should be dissolved in a part of the acid by heating, and then mixed with the balance of the acid and water. Two ounces of sulphuret of potassium in a gallon of water may also be used if it is heated to 160 degrees F. One ounce of sulphuric or muriatic acid in a gallon of water darkens the color produced by this last mixture.

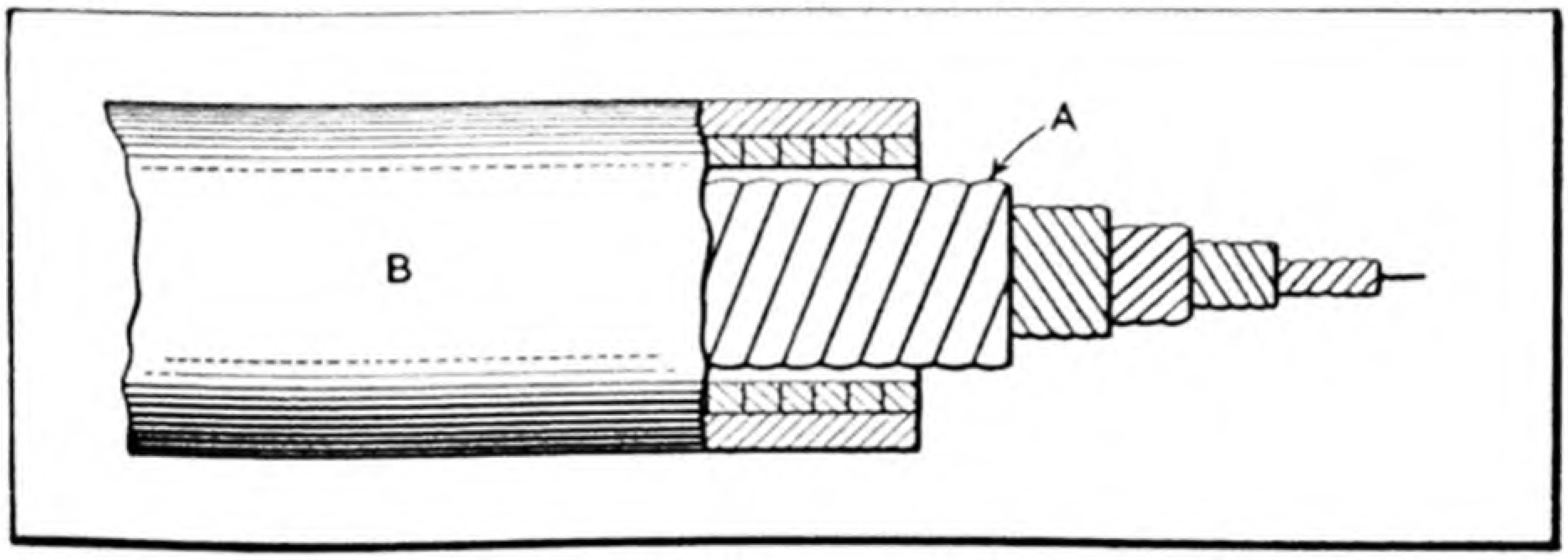
FLEXIBLE COUPLINGS. Flexible couplings are the most common mechanical means of compensating for unavoidable errors in alignment of shafts and shafting. When correctly applied, they are highly efficient. For joining lengths of shafting without causing loss of power from bearing friction due to misalignment, and for use in direct motor drives for all kinds of machinery, the value of the flexible coupling is now generally recognized. The fact that lineshafting will sag if of considerable length, makes the use of a flexible connection essential. Flexible couplings are not intended to be used for connecting a driven shaft and a driving shaft that are purposely placed in different planes or at an angle (joints for such service are usually called universal joints) but are intended simply to overcome slight unavoidable errors in alignment that develop in service. There is a wide variety of flexible coupling designs; most of them consist essentially of two flanged members or hubs, fastened to the shafts and connected by some yielding arrangement. The question of balance is an important matter in coupling selection or design, as an increasing number of couplings are used in connection with steam turbines, high-speed motors, and many other classes of machinery. It is not sufficient that the coupling be perfectly balanced when installed, but it must remain in balance after wear has taken place.

For small drives operating at moderate speeds where low first cost is the only consideration, there are several types of flexible couplings using leather, rubber, or fabric as the flexible element. Special types of couplings have been developed for continuous process work, as on steel rolling mills, where the capacity of the coupling for misalignment is really important. In designing couplings for such service, it is usual to sacrifice a considerable amount of over-all length in order to use what really amounts to two flexible couplings connected by an intermediate shaft, which may vary in length according to the probable maximum amount of off-center misalignment. An all-metal type of flexible coupling is adapted for heavy-duty work, because of the smaller size involved, longer life, and less cost — first and last.

Many drives are started suddenly, and one machine may impose a fluctuating or vibratory load on the other. For such drives it is often desirable to have a cushioning effect between the machines, which is supplied by coil springs or by laminated bundles of springs in the all-metal types. Flexible fabric couplings are noiseless in operation and yield sufficiently to cushion the shock when the clutch is engaged for starting. For this reason, the parts of the transmission are not subjected to such severe stresses as would otherwise be the case. These couplings are said to be durable and strong, but their use is restricted to " straight line " drives or cases where the driving shaft is inclined at an angle of only a few degrees.

FLEXIBLE SHAFTING. Flexible shafting is used for transmitting motion from a source of power usually to some kind of tool or abrasive wheel,

and it is so constructed that the driven tool or other device can be moved in any direction, owing to the flexibility of the shaft. Flexible shafting is sometimes used for driving a mechanically-guided tool, such as an auxiliary grinding wheel, which is held in the tool-post of a lathe or planer, but, in most applications of flexible shafting for the transmission of power, the object is to secure a free or universal movement of the driven member. For instance, a common type of portable grinding outfit consists of a motor which is mounted on a truck and drives a grinding wheel by means of a flexible shaft; as the wheel is held and guided by hand, it can be presented to any surface very readily. These flexible-shaft grinders are used for grinding castings or for cleaning castings by replacing the grinding wheel with a wire scratch brush. Flexible shafting is also extensively used for such work as



Sectional View of Wire-wound Flexible Shaft

the grinding of dies, driving small polishing wheels, driving drills of the portable type, rotating dental tools, and certain classes of surgical instruments, and for a great variety of other purposes, requiring a flexible transmission of power.

Flexible shafting consists of an inner core and an outer casing or covering. The core revolves within the casing and transmits motion from the source of power to the driven member. One type of core is composed of several layers of steel wire which are coiled or wound closely upon each other. (See Illustration.) Every alternate layer from the small one in the center to the outer layer is wound in an opposite direction. The cores of some flexible shafts are composed of links which are so formed and joined together that the required amount of flexibility is obtained.

FLOATING. The term floating is used in connection with lead storage batteries to indicate the condition when the batteries are permanently connected to the charging source without any means for regulating them, the battery then being said to " float " on the charging source. This arrangement is used when heavy momentary load fluctuations are present and when only approximate voltage regulation is required, or when it is necessary that the full capacity of the battery should always be available.

The term floating is also used to designate a machine part or a tool that is free to adjust itself to the other parts of the machine or to a piece of work, because of not being held rigidly in one position. See Floating Tool-holders.

FLOATING CORE. A core in a mold for making a casting is termed a floating core when it is not firmly supported and is lifted from its position by the molten metal as it flows into the mold. Floating cores are often the cause of unsound castings. The buoyant effect of the molten iron on a core is equal to about three times the weight of the core, if the core is solid, and very much more than that if it is hollow.

FLOATING FOUNDATIONS. See under Foundations for Machinery.

FLOATING LEVERS. See Differential or Floating Levers.

FLOATING TOOL-HOLDERS. A tool is said to " float " when it is not held rigidly but is free to move within certain limits. The floating or free movement may be in one direction only or in any direction. Many reamer- die- and tap-holders are of the floating type as they allow the die or tap to move in the direction of its axis, so that it is free to follow its own lead in case the forward movement is retarded by the backward pull or drag of the turret or tool-slide to which it may be attached. When a tool-holder is arranged to allow a die, tap, reamer, or other tool to move laterally or possibly in any direction, this is to permit the tool to align itself in case a hole is slightly off center. When the work to be operated upon is placed in a chuck either by hand or automatically from a magazine, a lateral or universal floating movement for the tools is especially desirable because of the difficulty of chucking parts in perfect alignment. Some tool-holders which are supposed to have a free floating movement to compensate for errors of alignment do not have this free movement when the tool is at work, because then there is considerable frictional resistance between the driving lugs or surfaces of the tool-holder.

FLOODED LUBRICATION. See under Lubricating Systems.

FLOW METER. The electrically operated flow meter provides means for accurately measuring the total flow of steam, water, air, gas, oil, etc., through pipes. Due to the electrical principle of operation, the indicating, curve-drawing and integrating instruments can be located any distance away from the pipe where the flow is being metered. This meter, as developed by a prominent electrical company, consists of three principal elements: The differential pressure producing device, the cast-iron meter body piped to the differential pressure producing device, and the electrical measuring instruments mounted on a panel. The cast-iron meter body is constructed in the form of a U-tube. Within one leg of this tube is a coil through which the current flows in its path through the meter body and back

to the panel. As the differential pressure increases, mercury is forced up around this coil, acting as a secondary inducing more current in the primary. This increase in current is indicated on the electric instruments and, as the differential pressure bears a definite relation to the flow, the current shown on the instruments will likewise bear a definite relation to the flow.

FLUID-COMPRESSED STEEL. Steel which has been subjected to compression before the ingots were entirely solidified, in order to secure a perfectly solid and homogeneous mass is known as fluid-compressed

FLUORINE. Fluorine is a pale greenish-yellow gas with a sharp odor. Its specific gravity is 1.265. The gas becomes liquid at a temperature of −187 degrees C. (−305 degrees F.), and the liquid becomes solid at a temperature of −223 degrees C. (−369 degrees F.). The most important compound of fluorine is that with hydrogen, with which it forms hydrofluoric acid (HF). Hydrofluoric acid is important because it dissolves glass, and can, therefore, be used for etching on glass. It is also used as an etching acid on metals.

FLUTES. The grooves which are cut in such tools as taps, reamers, drills, milling cutters, etc., in order to form cutting edges on the tools, and at the same time provide room for the chips produced by the cutting tools when in operation, are known as *flutes*. It is important that the flutes in the various types of machinists' tools be properly shaped, and special forms of milling cutters are generally used for producing the flutes. The cross-sectional shape of the flute varies according to the type of tool. See Taps; also Hot Flutes.

FLUXES. When metals are welded or soldered together, some substance which is known as a *flux* is used to prevent oxidation and to clean the surfaces to be joined, so that a solid homogeneous joint will be obtained. Fluxes are also used in connection with the smelting of metals, to promote fluidity, prevent oxidation, and remove objectionable impurities in the form of a slag.

In ordinary steel welding, fluxes are used to protect the heated surfaces from oxidation and to dissolve any oxide that may have formed. See Soldering Fluxes; Welding Fluxes; Aluminum Welding Fluxes.

FLY-CUTTER. The fly-cutter is a simple type of formed milling cutter that is often used for operations that will not warrant the expense of a regular formed cutter. The milling is done by a single tool or cutting edge which has the required outline. This tool is held in an arbor having a taper shank the same as an endmill. The advantage of the fly cutter is that a single tool can be formed to the desired shape, at a comparatively small expense.

FLYWHEEL. Flywheels are applied to engines and to many classes of machinery to equalize the energy exerted and the work done, and thereby

prevent great or sudden changes of velocity. The extent to which velocity changes may take place is the determining factor in all flywheel design. When the energy supplied to the flywheel becomes less than the work done by the machine, the wheel will begin to turn slower and slower, because it gives up its stored-up energy to supply the deficiency. The heavier the rim and the greater its velocity, the greater the energy that may be stored up in the flywheel, and the less will be the change of speed for a given amount of energy stored up. One hundred feet per second may be regarded as a safe rim speed for cast-iron wheels made in one piece, providing the design is such that there are no severe shrinkage strains in the casting. Ordinarily, strains exist, and, therefore, about 85 feet per second is as high a rim speed as should be considered good practice. If the wheel is made in halves or sections, the efficiency of the rim joint must be taken into consideration.

FLYWHEEL EQUALIZING SETS. See Equalizing Sets.

FOAMING. Foaming in boilers is caused by the presence of suspended matter in the water and also, to a certain extent, by the presence of oil. The alkaline salts of soda and potash may also produce the same result when found in the feed water in sufficient quantities. The direct cause of foaming is due to an increase in the surface tension of the water in the boiler. This requires a greater force for the bubbles of steam to burst through, and results in the churning of the top of the water into a foam, sometimes filling the steam space and passing over into the mains.

FOLLOW-BOARDS. Very light or thin patterns that are difficult to keep in shape during the building process, or are apt to be rammed out of shape in the foundry, are built on wooden forms called *follow-boards*. The follow-board is usually made to conform to the inner or cope side of the pattern and is used to build the pattern on, and also in the foundry to support it in the sand. Many master patterns for stove and furnace work are made in this way.

FOLLOW DIES. Follow dies are used for work which must be cut from the stock to the required shape, and, at the same time, be provided with holes or perforations. The principle of the follow die is that while one part of the die punches the hole in the stock, another part blanks out the work at a place where, at a former stroke, a hole or opening was punched, so that a completed article results from each stroke of the press; in reality, however, two separate operations have been performed, the operation being a progressive one in which the holes are first pierced, after which the stock moves along until the pierced section is in line with the blanking punch. Follow dies are also called "progressive" or "tandem" dies.

FOLLOWER. The name "follower" is often applied to the driven member of a gear train or other mechanism having a part that receives motion

from another member and follows it; usually the "follower" in a train of mechanism is the last driven member. The follower of an engine piston of the sectional type is the plate or cover that serves to retain the piston-rings. In cam design, the follower is the part that is reciprocated by the cam surface, or the part to which the cam imparts motion. Usually the follower is provided with a roller at its end in order to reduce the contact friction to a minimum.

FOLLOW-REST. For turning long slender parts, such as shafts, etc., a follow-rest is often used for supporting the work. A follow-rest differs from a steadyrest in that it is attached to and travels with the lathe carriage. One type has adjustable jaws which are located nearly opposite the turning tool, thus providing support where it is most needed. Other follow-rests have, instead of jaws, a bushing bored to fit the diameter being turned, different bushings being used for different diameters. The bushing forms a bearing for the work and holds it rigidly. Whether a bushing or jaws are used, the turning tool is slightly in advance of the supporting member.

FOOT. A foot is a unit of length; 1 foot = 12 inches = 0.3048 meter = 304.8 millimeters.

FOOT-POUND. Work is the result of the two elements, force and motion. When no motion results from the action of a force, no work is done. A jack-screw supporting a weight does no work, except when the screw is turned so as to raise the weight.

(*a*) In order to calculate the work done, the magnitude of the force applied is measured in pounds and the distance moved in feet. The product of these quantities, obtained by multiplying them together, is the work in *foot-pounds*. Or, briefly stated, work = force × distance.

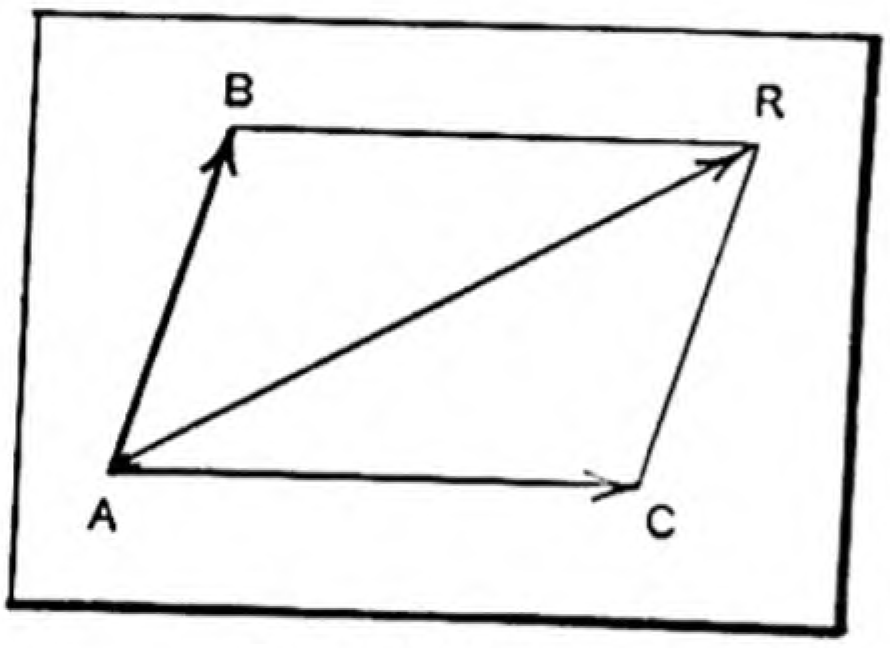
The foot-pound is called the *unit of work*, and may be defined as the work done by a force of one pound acting through a distance of one foot. In the estimation of work it is sometimes more convenient to multiply the resistance overcome by the distance, than to multiply the force applied by the distance, in which case work = resistance × distance.

FOOT-POUNDS PER BRITISH THERMAL UNIT. See Heat Equivalent of Work.

FOOT-VALVE. A "foot-valve" is sometimes placed at the lower end of the suction pipe of a pump to prevent the suction pipe from emptying while the pump is at rest; consequently, when the pump is first started, it does not have to exhaust the air from the suction pipe, and prompt starting of the pump is secured, assuming that the foot-valve is tight enough to retain the water in the suction pipe. This valve is of especial value when the suction lift or vertical height of the pipe is considerable. When the pump is

exposed to low temperatures during cold weather, it is advisable to have a drain fitted to the lower end of the suction pipe in order to empty the latter, in case the pump is to remain idle for some time and there is danger of freezing.

FORCE. A force, in mechanics, is defined as any cause tending to produce or modify motion. The units in which a force is usually measured are pounds or tons. A force has three characteristics which, when known, determine it. They are direction, place of application, and magnitude. The *direction* of a force is the direction in which it tends to move the body upon which it acts. The *place of application* is generally assumed to be a point, as the center of gravity. The *magnitude* is measured in pounds, as already stated. The single force which produces the same effect upon a body as two or more forces acting together, is called their *resultant.* The separate forces which can be so combined are called the *components.* The finding of the resultant of two forces is called the *composition* of forces, and the finding of two or more components of a given force, the *resolution* of forces. If two forces applied at a point are represented in magnitude and direction by the adjacent sides of a parallelogram (AB and AC in the accompanying illustration), their resultant will be represented in magnitude and direction by the diagonal AR drawn from the intersection of the two component forces.



Force Diagram

FORCED DRAFT. The forced draft method consists in forcing air under pressure into the ash-pit of a furnace, or into the retort of an underfeed stoker, and thus causing it to pass upward through the bed of fuel. It has the advantage of low first cost, and is also easily applied to old furnaces where it is desired to increase the power of the plant without installing additional boilers. One of the disadvantages of this system is that the pressure maintained in the ash-pit and furnace is liable to blow ashes and smoke into the fire-room if forced too hard. With moderate pressures, this may be avoided if care is taken to shut off the blast-pipe before opening either ash-pit or furnace doors. In admitting air to the ash-pit for forced draft, the ducts should be arranged to spread it as much as possible, and on this account it is usually introduced either through openings in the bridge wall or in the bottom of the ash-pit just inside the doors. Steel plate blowers of the centrifugal type are commonly used for forced draft. These may be of the regular form used for ventilating purposes, or of the multivane type, which is a common form of centrifugal fan having a large number of shallow vanes or blades.

FORCED DRAFT PRESSURES. The pressure required for mechanical or forced draft depends upon the rate of combustion, thickness of the fuel bed, and character of the fuel used. Average conditions will usually be covered between the extremes of from 0.75 to 2 inches of water column, corresponding to 0.44 and 1.16 ounce per square inch, respectively. The volume of air or gas to be handled by the blower will depend upon whether the forced or the induced system is used. For forced draft, about 18 pounds of air is required per pound of coal, which is approximately 230 cubic feet at 60 degrees F. The higher temperature of the gases passing through the blower when induced draft is employed makes it necessary to increase this volume of air about 30 per cent, to care for the expansion.

FORCED-FEED LUBRICATION. See under Lubricating Systems.

FORCED FITS. "Forced" or "pressed fit" is the term used when a pin, shaft, or other cylindrical part is forced into a hole of slightly smaller diameter, ordinarily by the use of a hydraulic press or some other type of press capable of exerting considerable pressure. A forced fit has a larger allowance than a driving fit, and therefore requires greater pressure for assembling. The proper allowance for a forced fit depends upon the mass of metal surrounding the hole, the size of the work, the kind and quality of the material of which the parts are composed and the smoothness and accuracy of the pin and bore. Crankpins, car-wheel axles, and similar parts which must be held very securely, are given forced or pressed fits rather than driving fits. The allowance per inch of diameter usually ranges from 0.001 to 0.0025 inch, 0.0015 inch being a fair average. Ordinarily, the allowance per inch decreases as the diameter increases; thus the total allowance for a diameter of 2 inches might be 0.004 inch, whereas, for a diameter of 8 inches, the total allowance might not be over 0.009 or 0.010 inch. In some shops, the allowance is made practically the same for all diameters, the increased surface area of the larger sizes giving sufficient increase in pressure. See Shrinkage Fits.

FORCE OF BLOW. The energy of a body raised to a given height and permitted to fall, as in the case of a drop hammer, is equal to the weight multiplied by the height through which it falls. Hence, the force of a blow cannot be expressed directly in pounds, but the energy with which a hammer will strike a piece of work can be expressed in foot-pounds. The average force of the blow, then, is equal to the number of foot-pounds divided by the amount of the penetration. When the force of a blow is calculated, the weight of the falling body should always be added to the energy due to the fall. If W = weight of falling body in pounds; S = the height through which it has fallen in feet; and d = distance in feet the object struck is

moved (or penetrated), then:

$$\text{Average force of blow} = \frac{WS}{d} + W.$$

FORCE OR FORCER. A "force" or "forcer" is a block of metal which forces sheet stock into every crevice in the impression of an embossing die. The term "force" is also used in connection with die-sinking, where it is often confused with the word "hub;" a *hub*, however, is a hardened steel punch used to form an impression in a die, and to use the word "force" in this connection is incorrect. A force is not employed in the making of the die, but is a part of the tools for producing a finished product in an embossing die. Forces are made from different materials, depending upon the character of the work, the design of the die, and the thickness of the metal being stamped.

FORCES, COUPLES. See Couples of Forces.

FORGE AIR PRESSURE. The air pressure for a forge commonly varies from 2 to 4 ounces per square inch, with an average of about 3 ounces. A pressure of 4 ounces at the blower has been recommended when the average number of fires does not exceed ten, and a pressure of 5 ounces when the number is more than twelve. Small forges with the blower close to them are adequately supplied with $1\frac{1}{2}$ ounces pressure. If the blower is some distance away and a long discharge pipe with many bends leads to the forge, even though the latter be small, it may be necessary to carry 3 ounces pressure or more, to overcome the friction in the air ducts. The volume of free air required by the average forge fire is about 140 cubic feet per minute. The exhaust fan for a blacksmith shop should have a capacity approximately four times that of the forge blower, and should operate under a pressure of about $\frac{3}{4}$ ounce.

FORGING BRASS. See Brass Forging.

FORGING BY COINING PROCESS. A modern and highly efficient method of finishing certain small forgings which are required in large quantities, is by squeezing in a powerful press equipped with suitable dies, those parts of the forgings which must be finished accurately to a given form and size. This method, which has been applied in the automotive field, represents the application of the coining-press principle to the finishing of various forged parts, such as different kinds of levers, spring shackles, axle spindles, head lamp brackets, steering and fan support arms, pedals, and connecting-rods. The parts of the forging which require coining or squeezing have a small allowance to provide metal for filling the die impression, and the squeezed parts are finished to size in one stroke of the press with the same degree of accuracy as is obtained by the removal of surplus stock through

cutting or machining operations. The coining type of press is used, although the term " squeezing press " has been applied to it on account of the variety of work which now comes within its range. See Cold Forging; also Cold-pressed Forgings.

FORGING HAMMERS. See Hammers, Forging.

FORGING MACHINES. Forging machines are made in a variety of designs, some being intended especially for bolt and rivet heading, and others for more general work. The form or shape into which a part is forged is governed by dies of the required shape and also by a heading tool or plunger which bends or upsets the heated bar of metal and forces it into the die impression. The die may have a single impression, or two or three impressions may be required in order to forge the part by successive operations. The reciprocating motion for the heading tool is obtained from a crankshaft which connects with the plunger slide by a pitman or connecting-rod.

On one type of forging machine, the crankshaft is driven through a clutch mechanism, so that the operator can control the number of revolutions the crankshaft makes before stopping, the arrangement being similar in principle to that of an ordinary punch-press. The clutch is tripped by means of a foot-treadle and the crankshaft is driven from a flywheel or gear wheel which revolves continuously. If but a single blow is required, the operator removes his foot from the treadle immediately after tripping the clutch, so that the machine stops automatically at the end of the backward stroke and after making one revolution. In case two or more continuous revolutions are required, the foot-treadle is held down until the required number of blows have been struck.

With another type of machine, what is known as a *lock* or *stop motion* device is used instead of a clutch. This mechanism is also controlled by a foot-treadle, and the device is so designed that the die mechanism is started from rest as the crankshaft, which rotates continuously, reaches the extreme end of the backward stroke. Upon releasing the foot-treadle, the movements of the forging mechanism stop automatically. Forging machines are equipped with some form of relief mechanism, so that, in case a piece of stock should be accidentally caught between the dies, no serious damage would be done.

FORGING PRESSES. Hydraulically-operated presses or the steam-hydraulic type are commonly used for forging large ingots, and are considered preferable to the steam hammer because they exert a steady pressure upon the forgings instead of a sharp blow, with the result that the forging action extends throughout the entire ingot, whereas the steam hammer tends to spread the surface metal without acting upon the center of the ingot to the required degree. There are two general types of these presses in use:

1. The regular hydraulic forging press, the water pressure for which is furnished by separate pumps. 2. The steam-hydraulic press, in which the hydraulic pressure is generated or produced by means of a steam intensifier. The former type is not now used to as large an extent as the latter, which has a number of advantages over the simple hydraulic type.

An hydraulic press exerts a continuous pressure which forces the semi-fluid material of a forging to flow under compression, which process tends to increase the density of the material. It is thus evident that, from the standpoint of improving the quality of the material in forgings, the press is superior to the hammer. Another advantage of the forging press over the steam hammer is that, for machines of equal capacity, the press, being entirely self-contained, requires a much lighter foundation, while the hammer must have a very massive foundation under the anvil block. The first cost of the forging press is higher than that of a steam hammer, but the difference in the cost of foundation alone tends to equalize the original investment.

FORGING PRESSES OF CRANK TYPE. Forging presses of the double-crank type are used for the manufacture of hammers, axes, pick-axes, adzes, mattocks, hoes, etc. A series of dies is arranged side by side and the part is forged in one or several heats by passing it from die to die. The slide is usually adjustable vertically, although these presses are sometimes furnished without slide adjustment and also without a clutch, for work requiring a continuous operation of the press, and where the design of the dies is such that no adjustment is needed.

FORMED CUTTERS. When pieces having an irregular outline are to be milled, it is necessary to use a cutter having edges which conform to the profile of the work. This is called *form milling*, and the cutter a *form* or *formed* cutter. There is a distinction between a *form* cutter and a *formed* cutter, which, according to the common use of these terms, is as follows: A formed cutter has teeth which are so relieved or " backed off " that they can be sharpened by grinding, without changing the tooth outline, whereas the term " form cutter " may be applied to any cutter for form milling, regardless of the manner in which the teeth are relieved. As indicated by this distinction between " formed " and " form " cutters, these cutters are provided either with regular milling cutter teeth or with eccentrically-relieved teeth. They are generally provided with the latter form, because in that case they can be ground on their faces without changing the form of the cutter. Form cutters are used for milling parts of special shapes to the required form. The small parts of sewing machines, guns, typewriters, and other pieces having an irregular and intricate shape are milled with formed cutters. The simplest types of form cutters are concave and convex cutters, the outline of which is a half-circle. These are used for milling half-circles,

cutting half-round grooves, and forming half-round edges. Formed cutters are made in a large variety of shapes and are used for many different purposes.

FORMED CUTTERS FOR SPUR GEARS. The invention of a milling cutter for forming gear teeth dates back prior to 1782. This cutter (now in the possession of the Brown & Sharpe Mfg. Co.) was made by Jacques de Vaucanson, a French mechanic. Evidently, the teeth were cut with chisels as they are very fine and rather crudely formed. Comparatively little is known about the types of early milling cutters used for gearing, etc., but the invention of the formed milling cutter in 1864 by J. R. Brown marked a great step in advance, as the contour of the cutting edge was not affected by successive sharpenings. This type of cutter is widely used for cutting gear teeth by the formed cutter method. See Gear-cutters.

FORM GRINDING. The grinding of machine parts by using a broad wheel which is shaped to conform to the shape required, and without traversing either wheel or work laterally, is known as *form grinding*. The wheel is wide enough to cover the surface to be ground, and, for round work, is fed straight in, thus grinding the entire surface at the same time, without a traversing movement such as is common to ordinary cylindrical grinding. For ordinary shapes, truing of the wheel is done without difficulty, and simply requires a special truing fixture which serves to guide the truing diamond mechanically. The term "form grinding," as applied to the manufacture of machine and automobile parts, is generally used to refer to the production of both straight and irregular-shaped surfaces. For round work, the term is used to indicate that the wheel is fed straight in without any traverse of the wheel or work. In order to differentiate between form grinding of straight and irregular surfaces, other names for the grinding of plain surfaces have been suggested, such as straight-in grinding, and wide-wheel grinding.

FORMICA. Formica is a non-metallic material made from sheets of cotton duck, the sheets being thoroughly impregnated with redmanol resin and made infusible and insoluble by the application of heat and pressure. An important application of formica is in making noiseless gears and pinions. Such gears are used for timing and ignition drives and on a miscellaneous variety of other machinery.

The tensile strength of formica in the direction of the laminations is 10,000 to 12,000 pounds per square inch, and the compressive strength, 24,500 pounds per square inch. The compressive strength perpendicular to the laminations is 47,000 pounds per square inch. The Brinell hardness is 34.4 and the hardness by scleroscope test, 65. The specific gravity is 1.38. The moisture and oil absorption is practically nil. The coefficient of linear expansion is about 0.00002 per degree Fahrenheit up to 150 degrees.

FORMICA MACHINING. Blanks can be cut from sheets of "Formica" either by a band saw or by trepanning tools in a boring mill or a drill press. To saw blanks, first describe a circle as a guide line, then use a 21-gage $3\frac{1}{2}$-point saw running at a speed of 5000 feet per minute. The saw should be sharp, with a $\frac{1}{64}$-inch set on both sides.

In drilling, use an ordinary high-speed drill whose point is ground to an included angle of 55 to 60 degrees. Another method is to grind the drill point slightly off center. The feed must be rapid and caution used to prevent the drill from lagging in its work, and the speed must be 1200 revolutions per minute.

For all machine operations on "Formica" gear material, provision must be made in grinding for the tools to clear themselves. For reaming, the entry of the reamer and the reaming process must be rapid. There must be no lag between the end of the reaming operation and the withdrawal of the reamer.

In turning the outside diameter and sides of blanks, the tools must be sharp and have 3 to 5 degrees more rake than is common practice for metal. A cutting speed of 750 feet per minute, which is equal to 720 revolutions per minute on a 4-inch diameter blank, is recommended. The depth of the cut can be $\frac{1}{16}$ to $\frac{1}{8}$ inch, but the feed should be 0.010 inch, regardless of the depth of the cut.

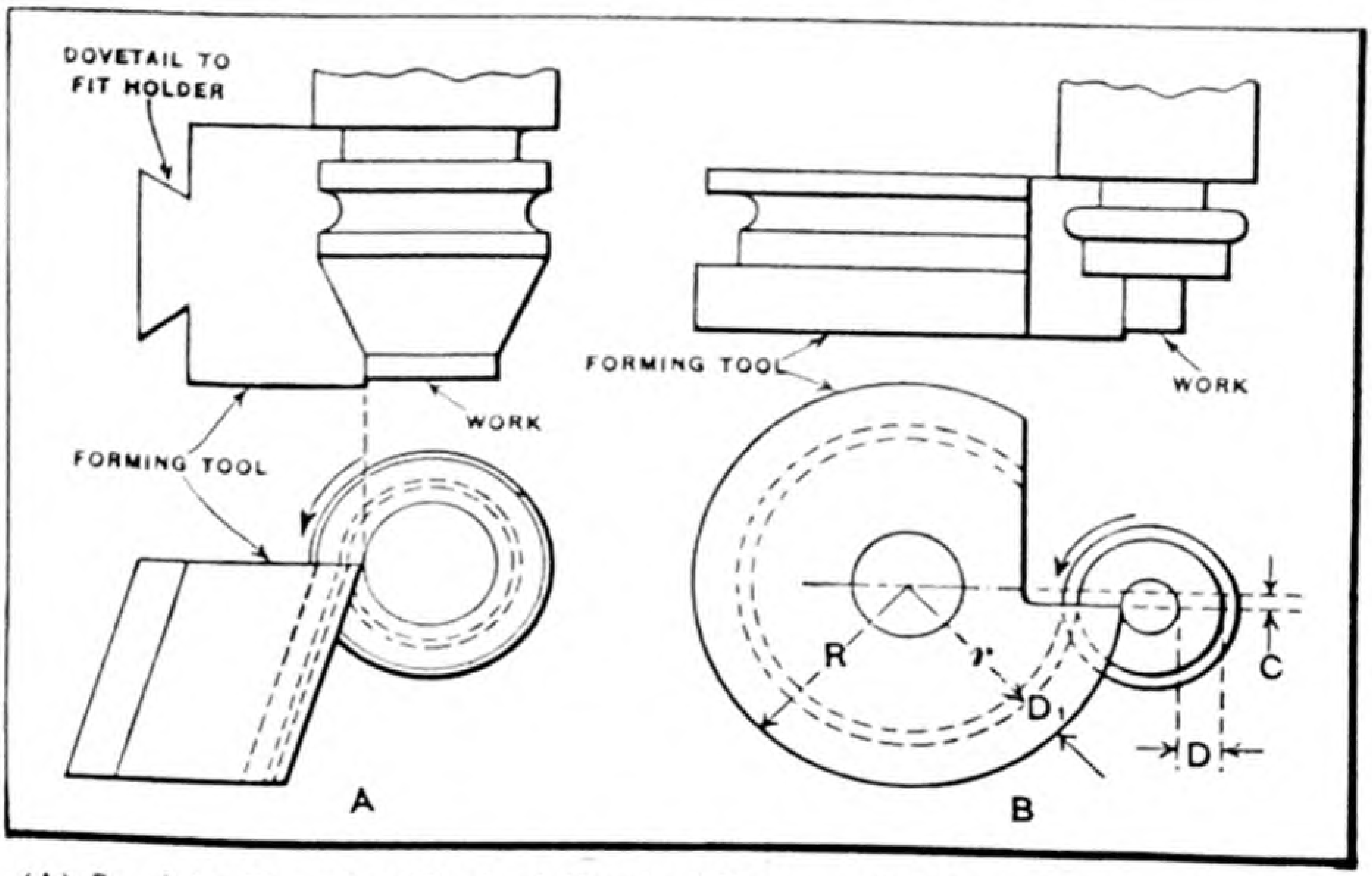
Teeth may be cut on a hobbing machine, shaper, or milling machine. The speed of the cutter should be 150 feet per minute, and the feed from 0.023 to 0.040 inch per revolution. It is advisable to back up the blank to prevent fraying or breaking out of the material as the cutter comes through. The backing plates can be economically made from hard wood.

FORMING DIES. Forming dies are a type of dies in which a blank is formed into a hollow shape by simply being pushed into a cavity of the required shape in the die, or a previously drawn cup is given a different shape by compressing it between a punch and die which conform to the shape desired. Drawing dies are also used for the formation of cup-shaped articles, but the drawing process differs from forming in that the stock is usually confined between two surfaces so that, when drawn radially inward from between them, no wrinkles can form. To define the difference between the two types in another way, forming dies shape the metal by compressing and bending it, whereas drawing dies so act upon a flat blank, or a previously drawn cup, that the shape is changed by drawing the metal as the punch moves relative to the die or *vice versa*.

FORMING LATHE. What is known as a *forming lathe*, or a *forming turret lathe*, is similar to an ordinary design of turret lathe but usually has a carriage between the turret and the headstock that is arranged for carrying

wide-forming tools; in some cases, there is a vertical slide at the rear, so that the forming tool may be fed in a vertical plane. Some forming and chucking lathes have a cross-slide for the turret and the latter carries the forming tools.

FORMING TOOLS. Forming tools are made in either straight or circular shapes. Forming tools for the lathe or planer are ordinarily made flat or straight. In some cases, a flat formed blade is bolted to a holder, but tools that are to be used very little are often made solid, the formed cutting edge being machined and filed on the flat forged end of the tool. When a number of different tools are needed, it is more economical to make one shank or holder and attach separate cutters or blades of the required form.



(A) Straight Forming Tool of Vertical Type. (B) Circular Forming Tool

Diagram *A*, shows a *straight forming tool* of the vertical or straight-faced type. This style of tool is used on automatic turning machines, etc., especially for large work. The *circular forming tool*, *B*, is used in preference to the flat or straight type for many classes of work, especially in connection with automatic screw machine practice, because it is more easily duplicated after a master tool for turning it is made. The circular tool can be ground repeatedly without changing its shape. The straight form of tool may also be ground repeatedly without affecting the shape, when it is made with a formed surface which is of uniform cross-section. Forming tools are also made which operate tangentially instead of radially; that is, the cutting edge, instead of moving in toward the center of the work, moves along a line tangent to the outside surface being formed.

FORMULAS. A formula may be defined as a mathematical rule expressed by signs and symbols instead of in actual words. In formulas, letters are

used to represent numbers or *quantities*, the term "quantity" being used to designate any number involved in a mathematical process. The use of letters in formulas, in place of the actual numbers, simplifies the solution of problems, and makes it possible to condense into small space the information that otherwise would be imparted by long and cumbersome rules. The figures or values for a given problem are inserted in the formula according to the requirements in each specific case. When the values are thus inserted, in place of the letters, the result or answer is obtained by ordinary arithmetical methods. There are two reasons why a formula is preferable to a rule expressed in words. 1. The formula is more concise, it occupies less space, and it is possible to see at a glance, the whole meaning of the rule laid down. 2. It is easier to remember a brief formula than a long rule, and it is, therefore, of greater value and convenience.

In chemistry, a formula is an abbreviation used to designate a chemical compound. It shows how many atoms of different chemical elements are contained in one molecule of the compound. For example, the chemical formula of ferric oxide is Fe_2O_3, which shows that one molecule of ferric oxide contains two atoms of iron, the symbol of which is Fe, and three atoms of oxygen, the symbol of which is O.

FORMULA TRANSPOSITION. A formula can be changed or "transposed" to determine the values represented by different letters of the formula. To illustrate by a simple example, the formula for determining the speed (s) of a driven pulley when its diameter (d), and the diameter (D) and speed (S) of the driving pulley are known, is as follows: $s = \frac{S \times D}{d}$. If the speed of the driven pulley is known and the problem is to find its diameter or the value of d instead of s, this formula can be transposed or changed. Thus: $d = \frac{S \times D}{s}$.

Changing a formula in this way is known as "transposition" and the changes are governed by four general rules.

Rule 1. An independent term preceded by a plus sign (+) may be transposed to the other side of the equals sign (=) if the plus sign is changed to a minus sign (−).

Rule 2. An independent term preceded by a minus sign may be transposed to the other side of the equals sign if the minus sign is changed to a plus sign.

As an illustration of these rules, if $A = B - C$, then $C = B - A$, and if $A = C + D - B$, then $B = C + D - A$. That the foregoing is correct may be proved by substituting numerical values for the different letters and then transposing them as shown.

Rule 3. A term which multiplies all the other terms on one side of the equals sign may be transposed to the other side, if it is made to divide all the terms on that side.

As an illustration of this rule, if $A = BCD$, then $\frac{A}{BC} = D$. Suppose, in the preceding formula, that $B = 10$, $C = 5$, and $D = 3$; then $A = 10 \times 5 \times 3 = 150$, and $\frac{150}{10 \times 5} = 3$.

Rule 4. A term which divides all the other terms on one side of the equals sign may be transposed to the other side, if it is made to multiply all the terms on that side.

To illustrate, if $s = \frac{SD}{d}$, then $sd = SD$, and, according to Rule 3, $d = \frac{SD}{s}$. This formula may also be transposed for determining the values of S and D; thus $\frac{ds}{D} = S$, and $\frac{ds}{S} = D$.

If, in the transposition of formulas, minus signs precede quantities, the signs may be changed to obtain positive rather than minus quantities. All the signs on both sides of the equals sign or on both sides of the equation may be changed. For example, if $-2\ A = -B + C$, then $2\ A = B - C$. The same result would be obtained by placing all the terms on the opposite side of the equals sign which involves changing signs. For instance, if $-2\ A = -B + C$, then $B - C = 2\ A$.

Formula Containing Power of a Number. — The power of a quantity or number may be given in a formula, and it may be desirable to transpose the formula so that the number itself may be determined. The formula $V = 0.5236d^3$ is for finding the volume of a spherical body. In this formula, V = the volume in cubic inches and d = the diameter of the sphere. Assume that the formula is to be transposed for determining the value of d. $V = 0.5236d^3$; then $d^3 = \frac{V}{0.5236}$. It follows, then, that the cube root of d equals the cube root of $\frac{V}{0.5236}$, or $\sqrt[3]{d^3} = \sqrt[3]{\frac{V}{0.5236}}$. As $d = \sqrt[3]{d^3}$, then $d = \sqrt[3]{\frac{V}{0.5236}}$. If the volume of the sphere is 4.1888 cubic inches, then $d = \sqrt[3]{\frac{4.1888}{0.5236}} = \sqrt[3]{8} = 2$ inches.

Formula Requiring Extraction of a Root. — The following example illustrates how a formula may be transposed to determine the value of a quantity covered by a root sign. If A equals the length of a hypotenuse of a right-

angled triangle, B equals the altitude, and C equals the length of the base, then $A = \sqrt{B^2 + C^2}$. If this formula is to be transposed for determining the value of C (lengths A and B being known), the first step is to remove the square-root sign, because C^2 cannot be transposed while it is covered by this sign. If A equals $\sqrt{B^2 + C^2}$, it follows that the square of A equals the square of $\sqrt{B^2 + C^2}$, and the square of $\sqrt{B^2 + C^2}$ is the same as $B^2 + C^2$; that is, the square of the expression is obtained by simply removing the square-root sign. The reason why this is true will, perhaps, be clearer if numerical values are substituted for the letters. Suppose $B = 4$ and $C = 3$, then $\sqrt{4^2 + 3^2} = \sqrt{25} = 5$, and the square of $5 = 25$. The sum of $4^2 + 3^2$ also equals 25.

It is evident, then, that $A^2 = B^2 + C^2$. The expression has now been changed so that it can be transposed, the square-root sign having been removed. Thus, $A^2 - B^2 = C^2$, or, if the formula is written in the usual manner with the letter representing the quantity to be determined placed on the left-hand side of the equals sign, $C^2 = A^2 - B^2$. Now the procedure is the same as for the formula previously referred to for determining the diameter of a spherical body of given volume. Thus, $\sqrt{C^2} = \sqrt{A^2 - B^2}$, and as $C = \sqrt{C^2}$, it follows that $C = \sqrt{A^2 - B^2}$.

FOUCAULT CURRENTS. Same as Eddy-currents.

FOUNDATIONS FOR MACHINERY. The materials commonly used are concrete, stone, brick, and wood in conjunction with concrete for machines subjected to considerable vertical shock. The principal characteristics of these materials are briefly as follows: Concrete is an ideal foundation material, as it becomes practically one solid piece and is much cheaper than a masonry foundation. Stone, in addition to being strong and durable, has great vibration-absorbing power, but is quite costly. Brick is not so durable as stone, but is cheaper and available everywhere. In a brick foundation, stones are usually placed under the parts of the machine which rest on the foundation. Good bricks should have plane faces, parallel, sharp edges, and sharp angles; their texture should be compact, and free from holes.

Proper Support for Machine Bed. — Machine bases or frames are of two types, namely, those that have inherent rigidity and so have need of support at three points only, and those without inherent rigidity, which must be supported at intervals in order to preserve their form and maintain perfection of alignment. The average machine user attempts to confer rigidity on machines of the latter type by bolting or grouting them firmly to a foundation. Such a procedure is fatal to the satisfactory use of planers, long lathes, and other machines of that type.

The bed of such a machine should be set on a good foundation, but should

never, under any circumstances, be bolted or grouted to that foundation. Instead, it should be supported on suitable wedges or other leveling devices at intervals of from three to five feet. Many shop men assume that a foundation will remain true, and that if a machine bed without inherent rigidity be grouted to the foundation, it will add to the stiffness and strength of the bed and eliminate vibration.

Foundations sometimes settle from $\frac{1}{4}$ to $\frac{1}{2}$ inch, and planer beds, for example, have been forcibly sprung over $\frac{1}{4}$ inch by being grouted firmly to a foundation that settled. As a result, the ways were no longer straight, the table vees touched only at the high spots, and the bearing surfaces were soon destroyed. If this machine had been set on leveling blocks, placed at about four-foot intervals, and the leveling blocks had been drawn up as often as necessary to compensate for the settling of the foundation, the planer would have remained accurate.

Types of Machine Foundations. — Machine foundations may be divided into rock-supported foundations, pile-supported foundations, and floating foundations. Rock-supported foundations are concrete or masonry structures which rest on rock or hard clay of such bearing power that the foundation does not settle measurably under the load of the machinery. Such a foundation may be in one piece or it may be a series of piers. If a foundation of this kind is obtainable at a reasonable cost, it is the best sort of machine foundation, but even a rock-supported foundation is subject to some seasonal movement, and long beds or frames must not be grouted or bolted to it.

When the foundation, because of the cost or for other reasons, cannot be carried down to the rock, it may be laid upon piles, columns, or beams that are rock-supported. Such a foundation is less subject to seasonal movement, but is more likely to settle at points where it carries concentrated loads.

Floating Foundations. — A floating foundation is one laid on an ordinary earth surface which has been properly leveled and compacted. The foundation must be stiff enough so that it transmits the weight equally to all parts of the surface, and large enough so that the distributed load does not exceed the safe bearing strength of the earth. It is usually in the form of a properly designed reinforced concrete slab.

Even a good floating foundation may settle, and provision must be made for keeping the machinery level. If the foundation carries only fixed weights, it can support a number of machines with only slight seasonal changes and very little settling. If, however, the loading varies from time to time, as, for instance, if the slab supports a column supporting a traveling crane, independent slabs should be provided for machines without inherent rigidity, while a common slab will do for a number of machines whose frames have inherent rigidity.

When a floating foundation is laid near a pile or rock-supported foundation,

many masons anchor it to the pile or rock-supported foundation, but the foundation is then not so good as it would be if it were free from such support, for if the earth settles ever so slightly, the foundation will no longer be true, while if the rock foundation be subject to moving loads, the floating slab will continually vary in its level.

Loads on Soils and Rocks. — Information about the bearing capacities of soils and rocks is not only useful in structural engineering, but also of value under certain conditions in connection with the installation of very heavy machinery requiring foundations. The ultimate resistance of various soils and rocks will be given in tons per square foot: Natural earth that is solid and dry, 4 to 6 tons; thick beds of absolutely dry clay, 4 tons; thick beds of moderately dry clay, 2 tons; soft clay, 1 ton; gravel that is dry, coarse, and well packed, 6 to 8 tons; soft, friable rock and shales, 5 to 10 tons; sand that is compact, dry, and well cemented, 4 tons; natural sand in a clean dry condition, 2 to 4 tons; compact bed-rock, northern red sandstone, 20 tons; compact bed-rock, northern sound limestone, 25 tons; compact bed-rock granite, 30 tons.

FOUNDRY COKE. See Coke.

FOUNDRY CRANE. This is a jib crane frequently used in foundry work. It is generally of heavy construction.

FOUR-POLE CIRCUIT-BREAKER. This is a circuit-breaker suitable for use on quarter-phase four-wire alternating-current circuits.

FOUR-STROKE CYCLE. See Cycles of Internal Combustion Engines.

FOX LATHE. The Fox lathe was first built by George H. Fox, some time between 1843 and 1859. Distinguishing features of the Fox lathe are a compound slide-rest (which, in later years, was usually surmounted by a tool turret) and a screw chasing attachment, known originally as "Nason's patent screw-chasing apparatus." This consists of a tool-holder clamped to a longitudinal round bar which is mounted in bearings so that it can both oscillate and slide endways. A half-nut, fixed to the bar, is brought into engagement with a short lead-screw when the operator pulls the chasing tool against the work. The Fox lathe is primarily a brass-working lathe, and is widely used in the manufacture of brass valves, gas fixtures, plumbing supplies, and other brass goods.

FREE AIR CAPACITY OF COMPRESSOR. See Air Compressor Capacity.

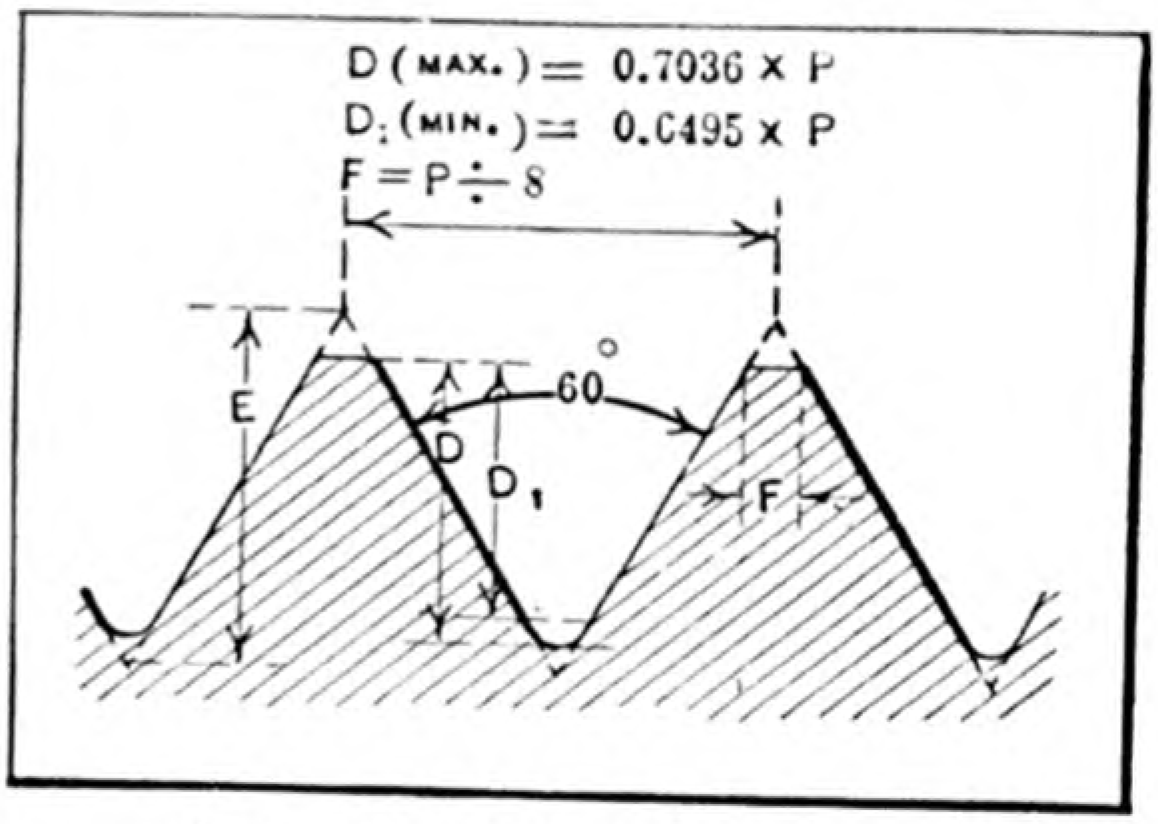
FREE-CUTTING STOCK. The term "free cutting" is applied to stock which may readily be machined and which does not form long, tough chips that tend to clog cutting tools. This free-cutting property is especially

important in connection with automatic screw machine and turret lathe practice. The standard specification of the Society of Automotive Engineers for free-cutting brass rod is as follows, the composition being in percentages: Copper, 60 to 63; lead, 2.25 to 3.25; iron, maximum, 0.15; other impurities, maximum, 0.25; zinc, remainder.

FREEZE-OUT. In blast furnace operation, the term "freeze-out" means that the iron and slag in the hearth has set in a solid mass, so that it is impossible to open the tap holes. This trouble is remedied by increasing the heat of the furnace until the metal is again melted.

FREEZING MIXTURES, RADIATOR. See Anti-freezing Mixtures.

FRENCH AND INTERNATIONAL THREADS. The French and International standard threads are of the same form as the United States standard, and the formulas given for the latter form of thread apply to the former. The pitches, however, are expressed in the metric measure, and are somewhat finer for corresponding diameters than in the United States standard thread system. A clearance space is ordinarily provided at the root by increasing the depth. The shape of this clearance is left to the manufacturer, but it is not to exceed one-sixteenth of the height E of the original triangle (see illustration). The International Congress which adopted this standard at Zürich, in 1898, recommended a rounded profile at the root as shown in the illustration.



International Standard Thread

FRENCH THERMAL UNIT. See Calorie.

FREQUENCY. The frequency of an alternating electrical current is the number of cycles or periods per second. The product of 2π times the frequency is called the *angular velocity* of the current Sixty cycles is the standard lighting frequency in the United States. If a lower frequency is used, fluctuations in the light are likely to occur. At 40 cycles, this flickering is not essentially objectionable, but at 25 cycles, it is quite perceptible, and this frequency is not used for lighting service except in an emergency.

FREQUENCY CHANGER. Many high-speed motor-driven portable tools and also certain classes of wood-working and metal-working machines are operated by high-frequency current due to the high speed, light weight, and compactness of the motor drive. An essential part of a high-frequency

installation is a frequency changer. Frequency changers convert the power of an alternating-current system from one frequency to another, without a change in the number of phases, or in the voltage. They are either used for obtaining, from a low-frequency system, a frequency high enough for lighting purposes, or as a means of interchanging power between systems operating at different frequencies.

Frequency-changer sets consist either of an induction motor driving a synchronous generator, or a synchronous motor driving a synchronous generator, the latter combination being the most common, especially where two systems are to be tied together and where reversible sets are required. The underlying theory of operation of the induction frequency changer of one manufacturer is virtually the same as that of an ordinary transformer. The machine consists of two motors coupled together, an induction motor driving a wound rotor motor in the opposite direction to which it would revolve as a motor. Thus there is generated in the rotary element a frequency higher than the frequency of the line, the frequency of the output being dependent upon the number of poles, the speed and the line frequency.

FRICTION. Friction is the resistance to motion which takes place when one body is moved upon another and is generally defined as " that force which acts between two bodies at their surface of contact, so as to resist their sliding on each other." The force of friction, F, bears (according to the conditions under which sliding occurs) a certain relation to the pressure between the two bodies; this pressure is called the *normal pressure* N. The relation between force of friction and normal pressure is given by the *coefficient of friction*, generally denoted by the Greek letter μ. Thus:

$$F = \mu \times N, \quad \text{and} \quad \mu = \frac{F}{N}.$$

For well-lubricated surfaces, the *laws of friction* are considerably different from those governing dry or poorly lubricated surfaces.

1. The frictional resistance is almost independent of the pressure per square inch, if the surfaces are flooded with oil.

2. The friction varies directly as the speed, at low pressures; but for high pressures the friction is very great at low velocities, approaching a minimum at about two feet per second linear velocity, and afterwards increasing approximately as the square root of the speed.

3. For well-lubricated surfaces, the frictional resistance depends, to a very great extent, upon the temperature, partly because of the change in the viscosity of the oil and partly because the diameter of the bearing increases with the rise of temperature more rapidly than the diameter of the shaft, thus relieving the bearing of side pressure.

4. If the bearing surfaces are flooded with oil, the friction is almost independent of the nature of the material of the surfaces in contact. As the lubrication becomes less ample, the coefficient of friction becomes more dependent upon the material of the surfaces.

When a body rolls on a surface, the force resisting the motion is termed *rolling friction.* This has a different value from that of the ordinary, or sliding, friction. Let W = total weight of rolling body or load on wheel, in pounds; r = radius of wheel, in feet; f = coefficient of rolling friction. Then:

$$\text{Resistance to rolling, in pounds} = \frac{W \times f}{r}.$$

The coefficient of rolling friction varies with the conditions. For wood on wood it may be assumed as 0.002; for iron on iron, from 0.002 to 0.005; iron on granite, 0.007; iron on asphalt, 0.012; iron on wood, 0.018.

FRICTION CLUTCH. A friction clutch is used for transmitting power from one machine member to another by means of frictional contact between members attached to the driving and driven machine parts. These clutches are made in many different designs, there being, however, four types that predominate; the conical clutch, the radial-expanding friction clutch, the contracting-band clutch, and the friction disk clutch. Friction clutches are used when it is desired to have a smooth and gradual engagement and disengagement of the driving and driven members.

FRICTION DIAL FEEDS. See under Power Press Ratchet Dial Feeds.

FRICTION GEARING. The term "friction gearing" is commonly applied to that type of gearing consisting of a driver made of some substance such as fiber or leather and arranged to operate by rolling in contact with a metallic driven wheel. The driving and driven wheels may be either cylindrical for driving parallel shafts or conical for driving shafts at an angle; when speed variations are required, a small driving disk may be arranged to revolve in contact with the side of a comparatively large driven disk, which also provides for reversing the rotation merely by shifting the driver to the opposite side of its central position on the driven disk. With the latter arrangement the axes of the driving and driven members are at right angles, and pure rolling contact is not obtained when using a driver of cylindrical form, since it makes contact with the driven disk at various diameters. Friction gearing provides a smooth, uniform drive, but toothed gearing is superior for most purposes because of its positive action and greater power-transmitting capacity. The latter may also be designed to transmit much more power, and at the same time insures maintaining the same relative

positions between the driving and driven members, which is important for many classes of mechanism.

"FRICTION HEAD" FOR LATHES. The geared friction head or headstock for turret lathes etc., has back-gears and friction clutches for engaging either the direct cone-pulley drive or the back-gearing. A great many turret lathes are provided with the geared-friction head. Many modern designs are also equipped with geared headstocks and either a single driving pulley or a direct-connected motor drive, instead of a cone-pulley.

FRICTION LOSS IN AIR COMPRESSORS. The friction loss of an air compressor, very careful tests show, is less by about 2 or 3 per cent than the friction loss of a steam engine, it being in the neighborhood of 6 per cent for the highest type of compressors. The friction in corresponding types of steam engines varies from 8 to 10 per cent.

FRICTION SAFETY COUPLING. This is a coupling in which one member is driven by friction, so that in case the power to be transmitted exceeds the normal requirements, the coupling will permit the driven member to slip.

FRICTION SAW. With a friction saw the "cutting" is done by a rapidly revolving soft steel disk, the edge of which is nicked slightly by means of a special chisel. When this disk is brought into contact with the part to be cut, a very rapid burning and abrading action occurs owing to the high speed and the resulting friction and heat. This disk is usually driven by a direct-connected electric motor which is mounted upon a horizontal carriage that is moved forward for feeding the disk against the work. These friction saws are used in steel mills and structural shops, etc., for cutting rails and bars of various shapes while cold. The disks have a rim speed of 24,000 feet per minute or higher and they cut very rapidly. The only sharpening necessary is to occasionally renick the edge of the disk. The best material from which to make friction disks for this purpose is soft steel having a carbon content of about 0.15 per cent; ordinary boiler plate or a brand of steel known as "soft flange-steel," which contains very little sulphur, gives satisfactory results. The disks should be turned true and roughened crossways on the edge with chisel cuts $\frac{1}{16}$ inch deep and about $\frac{1}{4}$ inch apart.

FRICTION-SCREW-DRIVEN PRESS. Friction screw or percussion presses are used for forging, hot-pressing, and stamping purposes. The driving mechanism of this type of press has one pulley with a friction wheel so arranged that either of two friction wheels may be shifted to engage the rim of the heavy central friction- or fly-wheel, attached to a vertical screw. By means of this screw, the ram of the press is raised or lowered. The main feature claimed for this class of press is the cumulative blow delivered, all

the energy of the flywheel being utilized as it comes to a dead stop; the operation is essentially that of pressing rather than that of a sharp blow or of hammering. Other advantages claimed for this type of press are that it provides for an "elastic" blow, the drive not being positive, and that, therefore, this design does not require bearings, shafts, etc., of as large dimensions as are required in presses with a positive drive. An important application of this type of press is in the hot pressing of brass and steel parts. See Hot-pressed Steel Parts and Hot-pressed Brass Parts.

FRISBY CLUTCH. This is a friction clutch having both a flat and a conical friction surface, which surfaces are used in combination. The clutch is thrown in by a leverage arrangement which forces the friction surfaces together.

FUEL, CALORIFIC VALUE. See Combustion of Coal; also Calorimeters.

FUEL, COAL DUST. See Coal Dust as Fuel.

FUEL, COLLOIDAL. See Colloidal Fuel.

FUEL OIL A kind of fuel which combines high heat value per unit of weight with extreme cheapness is that known as "fuel oil." This may be either a crude mineral oil or a mineral oil from which the gasoline and also the heavy residue have been removed. The fuel oil used for steam boiler purposes is a petroleum or crude oil in its natural state, with the lighter oils removed by distillation. There are two general methods of burning oil under boilers; both depend on a very fine atomization. The first and more common method is to inject high-pressure steam into the burning nozzles; the second consists in atomizing the oil by pressure. See Atomizers for Fuel Oil.

With a 50 per cent higher heat content in oil than in coal; a 5 per cent higher boiler efficiency due to the use of less excess air supply and the absence of combustible in the ash; a reduced labor cost for firemen and elimination of coal passers and ash handlers; a reduced fixed charge on storage and handling equipment; a reduced cost of maintenance due to omission of stokers — with all these advantages oil firing is conceded to be cheaper than coal firing, even if the former costs somewhat over 100 per cent more per ton. To this should be added the advantage of cleanliness, perfect control, and quick starting and stopping of any boiler.

FUEL-OIL ATOMIZERS. See Atomizers for Fuel Oil.

FUEL-OIL BURNERS. See Burners for Fuel Oil.

FUEL OIL, COAL AND GAS EQUIVALENTS. One gallon of fuel oil equals 13.1 pounds of coal, equals 160 cubic feet of natural gas. One

barrel of fuel oil equals 0.278 ton of coal, equals 680.6 cubic feet of natural gas. One pound of fuel oil equals 1.75 pounds of coal, equals 21.3 cubic feet of natural gas. One pound of coal equals 0.763 gallon of oil, equals 12.2 cubic feet of natural gas. One ton of coal equals 3.6 barrels of oil, equals 24,500 cubic feet of natural gas. The heating value of the average mid-continent fuel oil having a Baumé gravity of 26.9 is 19,376 British thermal units per pound of oil, and 143,950 British thermal units per gallon of oil.

FUEL OIL FURNACE TEMPERATURE. The flame temperature of fuel oil, about 4500 degrees F., is beyond the endurance of ordinary fire-brick used in a fuel oil furnace, and beyond the temperature ordinarily required for heating stock that is to be worked. In order to reduce the temperature to a point where the furnace lining will stand up, it is necessary to introduce about double the amount of air theoretically required for combustion. The amount of additional air must be varied to meet the requirements of the operation performed and the nature of the material. For example, ordinary soft steel may be successfully bent at a temperature of around 1800 degrees F., whereas high-carbon steel, if it is to be bent without rupturing the outer fibers, may require a temperature of from 2000 to 2100 degrees F.

FUEL OIL HEATING. The object in heating fuel oil in its storage tank is to bring it to a consistency that will permit it to be readily pumped through the pipe lines to the burners. Generally it is not necessary to heat the oil to a higher temperature than 175 degrees F. In fact, any temperature between this point and 125 degrees F. will be found satisfactory for most forge shop systems, provided the pipes are not subject to undue cooling at some point between the tank and the burners. The temperature of heavy oils must, of course, be kept somewhat higher than that of light oils. The following table will serve as a guide in determining the proper temperature: Oil of 28–32 Baumé gravity test to be heated to 125 degrees F.; 26–28 to 150 degrees; 24–26 to 180 degrees; 20–24 to 190 degrees; and 15–20 to 200 degrees F.

FUEL OIL HEATING VALUES. In order to determine the calorific values in British thermal units per pound of fuel oils, sixty-four samples of petroleum oils ranging from heavy crude oil to gasoline, representing the products of the principal oil fields in the United States, have been examined for calorific power. It was found that the oils varied in fuel value from about 18,500 to 21,100 B.T.U. per pound. In general, the decrease in calorific power with an increase in specific gravity is regular, so that the relation between the specific gravity and the heat value may be expressed approxi-

mately by means of a simple formula, as follows: B.T.U. per pound = 18,650 + 40 × (Number of Degrees Baumé − 10).

FUEL OIL SPECIFICATIONS. Fuel oil and furnace oil specifications of the American Oil Burner Association cover light, medium and heavy fuel and furnace oils. The grade of oil generally known to the trade as *light fuel oil* is intended for general industrial consumption and for use in burners adapted to a medium grade and medium viscosity fuel. The minimum and maximum flash points are 150 and 250 degrees F., respectively. (These flash points and others to follow are determined by the Pensky-Martens closed tester.) The maximum viscosity (Saybolt Universal) at 100 degrees F. is 125 seconds.

The *medium fuel oil* is similar to a grade listed in the United States Government specifications as Bunker Fuel Oil " B " and it is suitable for burners adapted to low grade oil of medium viscosity. The flash point is 150 degrees F. and the maximum viscosity (Saybolt Furol) at 122 degrees F. is 100 seconds.

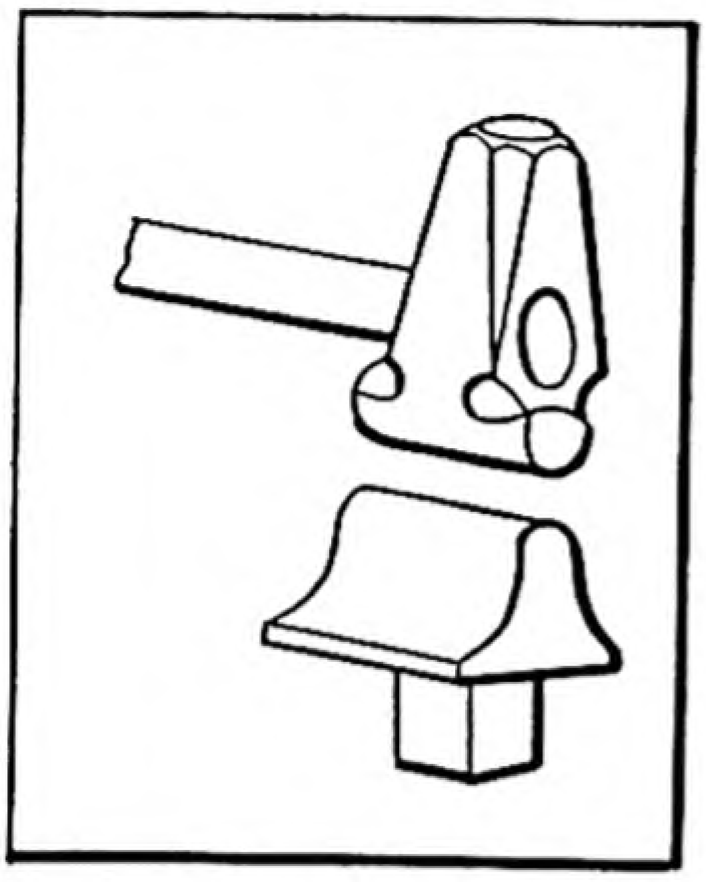
The *heavy fuel oil* is similar to a grade of fuel oil listed in the United States Government specifications as Bunker Fuel Oil " C " and it is suitable for burners adapted to a low grade of fuel oil of high viscosity. The minimum flash point is 150 degrees F. and the maximum viscosity (Saybolt Furol) at 122 degrees F. is 300 seconds. A water and sediment maximum of 1 per cent is allowed for the light and medium grades, and 2 per cent for the heavy fuel oil. The maximum sediment for the heavy oil is 0.25 per cent.

Furnace Oils. — The light furnace oil is a light distillate oil for use in burners requiring a high-grade fuel. The minimum and maximum flash points (Pensky-Martens closed tester) are 110 degrees F. and 165 degrees F. Only a " trace " of water and sediment is allowed. The medium furnace oil is also a distillate oil for use in burners requiring a high-grade fuel. The minimum and maximum flash points are 125 degrees F. and 190 degrees F. and only a " trace " of water and sediment is allowed. A heavy furnace oil is a grade generally known to the trade as light fuel oil; it is intended for general industrial consumption and it is for use in burners where a medium grade oil of low viscosity is required. The minimum and maximum flash points are 150 degrees F. and 200 degrees F., and the maximum viscosity (Saybolt Universal) at 100 degrees F. is 55 seconds.

FUELS, COMBUSTION ELEMENTS. See Combustion Elements in Fuels.

FULLER CELL. A Fuller cell is a primary cell or battery in which the zinc anode, which is in the form of a cone, is placed in a porous cup containing a little mercury. This cup is then filled with the electrolyte, which may be either dilute sulphuric acid or a solution of common salt, and is placed in

a glass jar which is filled with a depolarizer. The carbon cathode is then put in place. In a standard Fuller cell which has been widely used, the depolarizer is composed of 6 ounces of sodium bichromate, 17 ounces of sulphuric acid, and 56 ounces of water, which ingredients are heated together, forming chromium peroxide. The cell is used for open or closed circuits and has an electromotive force of from 2 to 2.1 volts.



Fullers

FULLERS. Fullers are used by blacksmiths for making grooves, breaking-down work, part of which is to be drawn down to smaller dimensions, and for a variety of other purposes. They have a fillet at the point where the light section joins the heavier stock and are made in pairs, top and bottom to match. (See illustration.) Top fullers are fitted to wooden handles and are used in the same manner as sets. Bottom fullers are made with shanks or stems to fit the hardie hole in the anvil.

FUN. A Japanese measure of weight, equal to 0.375 gram or 5.79 grains. One fun is divided into 10 rins.

FUNCTION. In mathematics, a function is a quantity or expression which depends for its value upon the value given to other quantities called independent variables or arguments. The circumference of a circle, for example, is a function of its diameter; when the length of the diameter is varied, the circumference varies also. In a table, the values by means of which the table is entered are known as arguments, while the tabulated values obtained from the table are functions.

FUNCTIONAL GAGE. See Gage Classification.

FUNCTIONS OF ANGLES. In order to introduce the values of the angles in calculations of triangles, use is made of certain expressions called trigonometrical functions or functions of angles. The names of these expressions are: sine, cosine, tangent, cotangent, secant, and cosecant. These expressions are usually abbreviated as follows: sin = sine; cos = cosine; tan = tangent; cot = cotangent; sec = secant; cosec = cosecant.

The *sine* of an angle equals the opposite side divided by the hypotenuse. The *cosin* of an angle equals the adjacent side divided by the hypotenuse. The *tangent* of an angle equals the opposite side divided by the adjacent side. The *cotangent* of an angle equals the adjacent side divided by the opposite side. The *secant* of an angle equals the hypotenuse divided by the adjacent side. The *cosecant* of an angle equals the hypotenuse divided by the opposite side.

It should be noted that the functions of the angles can be found in this manner only when the triangle is right-angled. The secant and cosecant, being merely the values of 1 divided by the cosine and sine, respectively, are not often used in calculations, and are not always included in tables of angular functions. See also Law of Sines and Cosines.

FUNT. A Russian measure of weight, equal to 0.4095 kilogram, or 0.9028 pound avoirdupois. Forty funts equal one pood.

FURLONG. A surveyor's length measure; 1 furlong = 10 chains = 220 yards = 660 feet = 201.17 meters.

FURNACES. Furnaces are used in connection with many different operations and processes, such as the hardening of steel, annealing, melting of metals, drying and baking, or for heating parts preparatory to a rolling, forging, or drawing operation. The furnaces used for these different classes of work vary greatly both in regard to size and design. The fuel may be oil, gas, coal, or coke, or electricity may be utilized for producing the necessary heat. The general classification is commonly based upon the position of the firebox or combustion chamber relative to the heating chamber, and these general classes are subdivided into types which are designated, usually, by terms indicating either the method of heating or the kind of work for which the furnace is intended. The name, in some instances, may also indicate some other characteristic constructional feature, as in the case of a *single-end furnace*, which has but one door or opening for the insertion and removal of work, or a *double-end furnace*, which has doors at both ends to provide for a progressive movement of the parts being heated.

Side-fired Furnaces. — The side-fired type of furnace is very commonly built with grates for the use of coal. For the use of oil fuel, suitable openings are made in the side walls, and the grates are covered with two or more courses of firebrick. By adjusting the air supply to give a long flame, it is possible to obtain a fairly uniform temperature across a heating chamber from 5 to 7 feet wide. Chambers 8 feet wide have given satisfactory service for some purposes. The conducting of the waste gases under the heating chamber floor will assist in heating the bottom of the work and increase the efficiency of the furnace. This type, with various modifications, has been used extensively for the annealing of brass, copper, and German silver.

End-fired Furnaces. — The heat distribution in end-fired furnaces is quite similar to that in the modified form of the side-fired furnace with the two fireboxes at one end. This type is practicable for heating chambers as large as 10 feet square, if the requirements of uniformity are not too strict. Oil fuel is sometimes introduced through the rear wall in the same manner as through the side wall of the side-fired type. This construction was formerly used for annealing brass, but is now more commonly applied to plate heating,

etc., where the mass of work is not deep, or, if deep, is relatively short so that the heating chamber can be made short and not require the false arch. Large furnaces for forge work are relatively long, with the stack or a flue at the end opposite the firebox and with doors at the side for the introduction of the work.

Under-fired Furnaces. — One of the most common types for small furnaces is the under-fired type. The same principles are sometimes applied to larger furnaces where the firing can be done below the mill floor line, as in a pit or basement. In heat distribution, this is the ideal type of furnace. For high-temperature work, this type has the disadvantage of subjecting the roof of the firebox or combustion chamber to an unusually severe condition, due to the relatively high temperature on top of it as well as underneath. This makes necessary the use of a very refractory material for that portion of the furnace, if the temperature required is high.

Over-fired Type. — An over-fired furnace is one in which the combustion chamber is above the heating chamber arch, the combustion gases being carried to the heating chamber through perforations in this arch, and leaving the furnace at the bottom of the hearth. This type of furnace is not commonly used, as the arch construction is expensive and delicate. As heated gas has a tendency to rise, extra draft must be used with an over-fired furnace, to draw the heat down. For extremely high furnaces, this type can be used in conjunction with the under-fired type. Its construction is also suitable for furnaces requiring removable hearths which are mounted on wheels, where there is no possibility of using the under-fired type.

Internally-fired Type. — In some cases the heating chamber and the combustion chamber can be combined. This arrangement is applicable to forge furnaces, rod and rivet heaters, etc., in which an intense heat is required, and the work will not be seriously affected by the direct action of the flame. Melting furnaces of some types are also internally fired. It is but rarely desirable to have the flame proper strike directly against the cold work, as combustion is thereby retarded and soot is often deposited on the work, particularly when oil fuel is used. This type is largely confined to the use of gas and oil fuel.

Hearth-fired Type. — In a hearth- or heating-chamber-fired furnace, the initial heat of combustion enters directly into the heating chamber. This type of furnace is usually constructed to allow the gases to come into direct contact with the work, and on account of fuel impurities it is not desirable for the heat-treatment of finished products. In carburizing, however, the work is protected and excellent and economical results can be obtained if there are proper flue outlets. This type of furnace can also be used for annealing if the product later undergoes machining. The removable type

of hearth can also be installed in this furnace. See also Electric Furnaces; Oil-burning Furnaces.

FURNACES, BRICKWORK. There are two prime essentials in furnace brickwork. The first is a quality of brick suited to the required service. The second is the laying of the brick with thin joints. Ordinary practice in laying common brick is utterly unsuitable for firebrick. Standard "9 straight" firebrick, uniform in size and straight within $\frac{1}{8}$ inch, should be dipped in a thin mixture of fireclay and water and laid with only what adheres to the bricks, and be rubbed to bed them in the wall, with the bricks in actual contact and the clay mixture merely filling the spaces left by what unevenness there may be on the surfaces. For joints which are necessarily thicker, the clay mixture should be thickened with sea sand, ground firebrick, or carborundum fire-sand which will not shrink as much as the clay. Lime should never be used in the laying of firebrick. Portland cement is used by some masons and is probably desirable as a binder in laying No. 2 quality firebrick where the temperature to which it will be exposed is less than 2500 degrees F. For high temperature duty particularly, the fireclay with which the bricks are laid should be of the same (or better) quality as the bricks, and preferably of the same brand.

FURNACE TEMPERATURE CONTROL. The temperature of heat-treating furnaces may be controlled in several different ways: First, the furnace operator may take the pyrometer readings and regulate the furnace according to his own judgment; second, the operator may simply adjust the furnace to maintain a given temperature according to signals from a man in charge of the temperature control for all the heat-treating furnaces; third, the signals of the furnace operator may be controlled automatically by a special form of pyrometer which is previously set for whatever maximum and minimum temperatures are desired; and fourth, the control may be entirely automatic. When the control is by some method of signaling, either colored lights or a bell may be used. If lights are employed, there are generally three — a red, white, and green combination being common. These lights are placed near the furnace. The red light may show that the temperature is too high, the white light that it is correct within certain limits (possibly 15 or 20 degrees) and the green light that it is too low. Lights are sometimes used in combination to vary the signals. For instance, when a furnace is loaded with work, the temperature is reduced considerably, the amount depending upon the size of the work and the number of pieces inserted. When the temperature has increased to a certain point, two lights may be switched on to show that it is still considerably below the required temperature, and then one light may be used to show that it is approaching the correct temperature but is still somewhat low. Finally, a different light

may indicate that the correct temperature has been reached. See also Pyrometers.

FUSES IN ELECTRICAL CIRCUITS. An electric fuse is simply a conducting element of such dimensions that it will melt at a predetermined current value, and thus break the circuit and prevent a dangerous temperature increase due to abnormal current conditions. Although arranged in many forms, fuses are simply metal strips or wires that melt, or fuse, when the current reaches the predetermined value. They are divided into two classes: (1) Those designed to protect the circuit and apparatus against both short circuits and definite amounts of overloads. (2) Those designed to protect the system only against short circuits. To the first class belong link and enclosed fuses of the National Electric Code that open on 25 per cent overload. To the second belong the expulsion fuses, which blow at several times the current they are designed to carry continuously. Fuses differ from plain over-load circuit-breakers in that they are governed by both the time and quantity of the current, while the overload circuit-breaker is governed solely by the quantity of the current.

FUSIBLE METALS. Fusible metal is the name applied to certain metal alloys generally composed of bismuth, lead, and tin, and sometimes also containing cadmium, which possess the property of melting at comparatively low temperatures. One of the earliest discoveries of a metal alloy which would melt at a low temperature was that of Newton, and the metal known as *Newton's fusible metal* contained 50 parts of bismuth; 31.25 parts of lead; and 18.75 parts of tin. This metal melts at a temperature of 201 degrees F. Another of the early fusible metals was discovered by Darcet. This alloy contained 50 per cent of bismuth; 25 per cent of lead; and 25 per cent of tin; it melts at a temperature of about 200 degrees F. The addition of cadmium produces an alloy which melts at a still lower temperature. An alloy containing 50 parts of bismuth; 25 parts of lead; 12.5 parts of tin; and 12.5 parts of cadmium will melt at a temperature as low as 149 degrees F. By the addition of mercury to the metal discovered by Darcet, the melting point may be reduced to as low as 113 degrees F.

Fusible metals are used for a number of purposes where an alloy that will melt at a low predetermined temperature is required, as in automatic sprinkler heads, in fuses in electric circuits, and for fusible plugs in steam boilers. In automatic fire sprinklers, the water pipe lines are closed with the fusible metal. In the event of fire, the rise of temperature will melt this metal and the water will be liberated. In steam boilers, fusible plugs are inserted in the furnace crown sheets as a safeguard in case the water level should fall too low. When the fusible plug is no longer in contact with the water, it will be heated to such a temperature that it will melt and allow the steam to

escape, thus giving warning of the condition existing in the boiler. See Wood's Metal.

FUSION. The term " fusion " applies to the melting of a solid body, or to the changing of the state of a body from the solid to the liquid condition. It has been established, beyond doubt, that all substances can be transformed into a solid state at some temperature, but, in the case of gases, the temperature must be exceedingly low. It has also been established that all solid substances can be fused or melted and transformed into the liquid state, provided the temperature is high enough. Of the chemical elements, it appears that carbon will stand the highest degree of heat without melting. When changing from the solid to the liquid state, a certain amount of heat is used to accomplish this change. This heat does not raise the temperature of the body and is called the *latent heat of fusion*. This heat is applied to the body at the melting point and is absorbed by the body, although its temperature remains nearly stationary during the whole operation of melting. The latent heat of fusion varies for different substances.

GAGE. Any tool or instrument used for taking measurements might properly be called a "gage," but this term, as used by machinists and toolmakers, is generally understood to mean those classes of tools which conform to a fixed dimension and are used for testing sizes, but are not provided with graduated adjustable members for measuring various lengths or angles. There are exceptions, however, to this general classification. Gages may be made or set to measure one or more dimensions, and they are used for determining if manufactured parts have been made to agree with prescribed dimensions. If a gage is provided with means for measuring the maximum and the minimum dimensions to which a given piece may be made, it is known as a "limit gage" because it is the means of determining if the part is made within the predetermined limits set for it.

Gages are used in interchangeable manufacture, where a number of similar parts are to be made, all of which may be measured by the same gage and the accuracy of which, within the prescribed limits, may thereby be assured. As the name implies, *working gages* are used by the workmen at the bench or machine in gaging the work as it is being made. *Inspection gages* are used by the inspectors in checking the product to determine if it has been properly made to the required dimensions. *Reference gages* are used for testing or checking the inspection gages from time to time, to make sure that they have not become unsuitable, through wear or otherwise, for the use for which they are intended. These very general classes of gages are made in a large variety of designs and sizes. See Limit Gages; Master Gages; Reference Gages; Temperature Standards for Gages.

GAGE-BLOCK ADHESION. A remarkable property of precision gage blocks is their adhesiveness to one another. When wrung together they will resist separation in a direction at right angles to the faces in contact, with a force considerably greater than the atmospheric pressure on the area of contact. This phenomenon has caused some to believe that actual molecular adhesion takes place when surfaces that are nearly perfect planes are brought into intimate contact. The error of this theory has been revealed by investigations showing that the adhesion results from the presence of a very thin liquid film. Some blocks of hardened steel were prepared, each weighing $1\frac{1}{2}$ ounce and having surfaces of 0.7 square inch polished flat to within a millionth of an inch of accuracy, and these were used to test the adhesive properties of many liquids. The contact faces were carefully freed from moisture and grease with alcohol before being coated with a very thin film of the liquid under test. When wrung together while perfectly clean, they fell apart, under their own weight; in order to separate blocks which were held together by films, a force ranging from 17 pounds for Rangoon oil to 22 for lubricating oil, 29 for turpentine, and

35 for condensed water vapor was necessary. After washing the hands with soap, blocks rubbed on them showed adhesion as high as 90 pounds. There was no adhesion from volatile liquids, such as alcohol and benzine; and very little from viscous liquids, such as glycerine and glucose. The microscope showed that the films, drawn out in thin lines, covered only a tenth or less of the metal faces. From varied experiments it appeared that in the case of paraffin film, for instance, the 27 pounds required to part the plates included about one pound due to atmospheric pressure, one to surface tension and 25 pounds to the actual tensile strength of the liquid. The tensile strength of water seemed to be as high as 443 pounds per square inch.

GAGE CLASSIFICATION. The gages used in machine-building plants may be included in one of the following classes, depending upon the use to which the gage is put.

Master Gages. — These gages are used only as checks for inspection or working gages. The master for a ring gage is a plug, and the master for a plug gage is usually another plug from which a measurement may be taken for comparison. A basic size gage may also be known as a " master."

Inspection Gages. — Gages of this class are used by the inspector to check work coming either from the factory or from outside sources.

Working Gages. — Working gages are used in machine-building plants for checking the work, either in a semi-finished or finished state. They are made to a tolerance within the inspection gage tolerance, or larger than the minimum dimension of the work and smaller than the maximum dimension.

Functional Gages. — Functional gages are used to test the functional relation of parts, as for example the relation of two such mating parts as a spline shaft and a hole.

GAGES FOR MATERIALS. The thicknesses of sheet metals and the diameters of wires conform to various gaging systems. These gage sizes are indicated by numbers, and in MACHINERY'S Handbook and in other engineering handbooks, will be found tables giving the decimal equivalents of the different gage numbers. Much confusion has resulted from the use of gage numbers, and in ordering materials it is preferable to give the exact dimensions in decimal fractions of an inch. While the dimensions thus specified should conform to the gage ordinarily used for a given class of material, any error in the specification due, for example, to the use of a table having " rounded off " or approximate equivalents, will be apparent to the manufacturer at the time the order is placed. Furthermore, the decimal method of indicating wire diameters and sheet metal thicknesses has the advantage of being self-explanatory, whereas arbitrary gage numbers are not. The decimal system of indicating gage sizes is now being used quite generally, and gage numbers are gradually being discarded. Unfor-

tunately, there is considerable variation in the use of different gages. For example, a gage ordinarily used for copper, brass and other non-ferrous materials, may at times be used for steel, and vice versa. The gages specified in the following are the ones ordinarily employed for the materials mentioned, but there are in some cases minor exceptions and variations in the different industries.

GAGES FOR RODS. The Brown & Sharpe or American Wire Gage is used for rods of non-ferrous metals, such as brass, copper and aluminum. Stub's Steel Wire Gage is used to some extent for tool steel, drill rod and wire, and the Twist Drill and Steel Wire Gage is used for twist drills and steel drill rods.

GAGES FOR SHEET METALS. The U. S. Standard Sheet Metal Gage is used by the manufacturers of commercial iron and steel sheets or plates, including planished, galvanized, tinned and terne plate; black sheet iron; blue annealed soft steel; steel plate; hot-rolled sheet steel; cold-rolled sheet steel; hot-rolled monel metal; and cold-rolled monel metal. The American or Brown & Sharpe Wire Gage is used for sheets of brass, phosphor-bronze, aluminum and German silver. The Birmingham Wire Gage is used for strip steel, steel bands, hoop steel, crucible spring sheet steel, and sheet copper. The Zinc Gage is used for sheet zinc only.

In England the Birmingham Gage legalized in 1914 is used mainly for iron and steel sheets and hoops. This 1914 Birmingham Gage differs from the older Birmingham Wire Gage (see wire gages in Machinery's Handbook). Another older gage known as the Birmingham Metal Gage is used for brass sheets. For aluminum sheets, the Imperial Wire Gage is used in England.

GAGES FOR TUBING. The Birmingham Wire Gage is used for the following classes of tubing: Seamless brass, seamless copper, seamless steel, and aluminum. The Brown & Sharpe Wire Gage is used for brazed brass and brazed copper tubing.

GAGES FOR WIRE. The Brown & Sharpe or American Wire Gage is generally used in the United States for all bare wire of brass, copper (except bare copper telephone wire) phosphor-bronze, German silver, aluminum, and zinc; for resistance wire of German silver and other alloys; for insulated wire of aluminum and copper. The Steel Wire Gage (also known as (1) Washburn & Moen, (2) American Steel & Wire Co., (3) Roebling, and (4) National Wire Gage) is used for bare wire of galvanized and annealed steel and iron (except telephone and telegraph), and also for spring steel wire. The American Steel & Wire Co.'s Music Wire Gage is used for music wire. The Birmingham Wire Gage sizes are very generally used

for iron and steel telephone and telegraph wires, but the sizes of bare copper telephone wires, usually conform in the United States, to the Standard Wire Gage used in England. This Standard Wire Gage (also known as the Imperial Wire Gage and as the English Legal Standard) is used in England for all wires. The abbreviation S. W. G. is sometimes used for Standard Wire Gage, also the abbreviation N. B. S. for New British Standard Wire Gage. This gage was legalized in Great Britain in 1883.

GAGE TEMPERATURE STANDARDS. See Temperature Standards for Gages.

GAGE TOLERANCE. According to the practice of a prominent manufacturer of gages, a tolerance equal to 10 per cent of the tolerance on the work is generally allowed on ordinary working and inspection gages. Thus, if the work tolerance is 0.005 inch, the gage tolerance equals 0.0005 inch for both the working and inspection gages. There is a difference, however, between the maximum and minimum dimensions of the working and inspection gages. The minimum size of the working gage is made 10 per cent of the tolerance *larger* than the minimum size of the inspection gage, and the maximum size of the working gage is made 10 per cent of the tolerance *smaller* than the maximum size of the inspection gage.

GAGGERS. In molding, if a body of sand that must be lifted away with the cope extends below the parting, it is strengthened by the use of gaggers. These are usually L-shaped pieces of cast or bar iron. The upper part of the gagger, when rammed tightly between the cope bars, helps to support a hanging body of sand.

GALALITH. Galalith is a material used for electrical insulation. It is made by heating the residue of skimmed milk after the water has been extracted. The material is easily molded and bent, but has the disadvantage that it is highly hygroscopic; that is, it absorbs water in a large degree. The dielectric strength of galalith is given as from 6000 to 8500 volts per millimeter (0.0394 inch).

GALLON. See Liquid Measure.

GALLOTANNIC ACID. A lustrous, faintly yellowish, amorphous powder. It is soluble in water and alcohol; decomposes at 210 degrees C. It is also known as acid tannic. Its chemical composition is $C_{10} H_{14} O_9$.

GALVANIT PROCESS. The galvanit process is an electroplating method whereby metals of various kinds may be coated with nickel, silver, zinc, or other metals with no more difficulty or exertion than that of using an ordinary polishing powder. The method consists in the use of a mixture of pulverized materials in which the metal of which the coating is to be

made is the main constituent; the deposition process consists simply in applying the powder by means of a rag or brush, and rubbing the object to be treated in the presence of moisture.

GALVANIZED WIRE ROPE. Galvanized wire rope is used where the rope is exposed to extreme weather conditions, especially for derrick guys and for ship's rigging, for smokestack guys, etc. Single galvanized wire rope strands are also used for this purpose. Large galvanized wire ropes are used for hawsers and mooring lines on board ship, and for towing purposes. Galvanized rope is not used for general hoisting purposes or where it must be wound upon drums, because the zinc used for the galvanizing wears off rapidly when running over sheaves and drums, and when exposed to abrasion. Galvanized ropes of the same diameters as regular wire ropes have about 10 per cent less strength. Galvanized wire ropes are made in various constructions from six strands with seven wires to the strand, to six strands with thirty-seven wires to the strand.

GALVANIZING. Galvanizing, in general, is the process of coating one metal with another; the name, however, is more especially applied to the coating of iron or steel products with zinc to prevent corrosion by excluding moisture. Tin and lead are sometimes used as coating materials, but are less effective. Aluminum fulfills all the requirements of a good coating better than any of the commercial metals, but zinc is used because of its lower cost. Iron parts are galvanized by dipping them in molten zinc; this is the process generally known as *galvanizing*. The galvanizing of wire, whether in the form of netting or single wire, is a continuous process, so that the factor of speed is introduced. The amount of zinc deposited can be regulated to a nicety by varying the temperature or speed, or both. The wire passes through a flux and then through the molten metal, and emerges through a part of the bath continually skimmed from oxide.

Zinc for Galvanizing. — Zinc used for galvanizing should not contain more than 0.5 per cent of iron. It will absorb from 1 to 4 per cent, but each per cent absorbed raises the melting temperature of the bath, so that the zinc becomes thick and pasty; the absorption of iron from the articles being coated and from the sides of the container requires frequent skimming of the bath.

Cleaning and Galvanizing Baths. — The articles to be coated must first be thoroughly cleaned by pickling in a sulphuric-acid or hydrofluoric-acid bath. Before the articles are dipped in the molten zinc, the surface of the bath is covered with a flux of sal-ammoniac, which not only prevents the zinc from oxidizing, but assists the iron to take the zinc quickly and evenly. The temperature of the bath may vary from 800 to 1000 degrees F., depending upon the character of the work to be galvanized. After the articles

are thoroughly heated and covered with the zinc, they should be withdrawn and the excess of metal shaken or wiped off, depending upon their shape. They are then dipped into hot water. Spangle is produced by the immersion of the material, while hot, into water; it adds to the appearance and finish of the goods. It is possible, however, by slow cooling apart from water, to produce galvanized articles free from spangle; it has been claimed that such goods have a more uniform coating.

Improved Method of Galvanizing. — As actual fusion of the two metals is not obtained by dipping an article in molten zinc, the zinc coating does not thoroughly protect the iron surface underneath. This defect is avoided by a process in which the iron or steel is so prepared that the zinc is deposited into its pores. After being steeped in sulphuric acid, the parts to be coated are placed in a solution of mercuric chloride and then heated, resulting in the decomposition of the mercuric chloride and precipitation of metallic mercury, which forms an amalgam on the surface. The part to be coated is then plunged for three minutes into a zinc bath heated to 930 degrees F. The zinc coating deposited by this method adheres very strongly to the metal. As the zinc penetrates into the pores of the iron, should a portion of the coating be worn or peeled off, the iron will not rust owing to the presence of sufficient zinc on the surface to protect the metal from the action of the atmosphere. In other words, there is a perfect alloy or association of the two metals at the point of juncture.

GALVANOMETER. The galvanometer is an instrument for detecting or measuring electric currents, and is generally applied to instruments indicating electric currents on a scale having divisions of arbitrary units, as opposed to the instruments known as "ampere-meters," which give directly the strength of a current in amperes. A great number of different instruments have been devised both for direct and alternating current. The principle on which one of the types of direct-current galvanometer works is based upon the fact that a small magnet, when suspended in the center of a coil of wire through which current is passed, has a tendency to place its magnetic axis in the direction of the magnetic field of the coil at that point. The galvanometer may also be constructed with a suspended coil and a fixed magnet. In alternating-current galvanometers, the instrument may be made by suspending, within a coil of insulated wire, a needle of soft iron placed with its axis at an angle of 45 degrees to the axis of the coil. When an alternating current passes through the coil, the soft iron needle has a tendency to place itself in the direction of the axis of the coil. Other types have also been devised. A *ballistic* galvanometer has its movable parts damped as little as possible, so as to make it adaptable for quick measurements, such as electric charges or discharges. The deflection

is, therefore, proportional to the quantity of electricity rather than to the current.

GANG DRILLING MACHINE. See Drilling Machines.

GANG MILLING. A great deal of the work done on milling machines (especially the horizontal types) is machined by a combination or "gang" of two or more cutters mounted on one arbor. This is known as gang milling. If a plain cylindrical cutter were placed between two side mills a gang cutter would be formed for milling several surfaces. This would not only be a rapid method, but one conducive to uniformity when milling duplicate parts.

GANG OR MULTIPLE DIES. When large numbers of blanks are required, *multiple* or *gang dies* are sometimes used. These dies have a number of duplicate punches with similar openings in the die-block and cut as many blanks as there are punches, at each stroke of the press. The term "gang" die is often applied to a follow die; this usage is generally conceded to be incorrect, however, as the word "gang," as used in mechanics, ordinarily means a combination of similar tools so arranged as to act simultaneously for producing duplicate parts.

GANG PLANING. When a number of duplicate parts have to be planed, much time can often be saved by arranging the castings in a straight row along the platen so that they can all be planed at the same time. This method, called gang planing, enables a number of parts to be finished more quickly than would be possible by machining them separately, and it also insures duplicate work.

GANG PRESSES. Power presses of the gang or multiple type are especially designed for operating long narrow dies requiring considerable power, such as those used for gang-punching rivet holes in sheets for boilers and tanks, riveting dies, corrugating and forming tools, etc. A typical press of the gang type has a gap frame and double-crank drive for the slide. The cam-actuated stripper is generally used in connection with these presses. This form of stripper permits the use of much shorter and more durable punches than can be employed with stationary strippers. Moreover, the stripper comes down upon the metal and straightens it (if not too thick), holding it while punching and stripping takes place. After the punches have moved up through the sheet, the stripper also ascends.

Gang Presses of Double-action Type. — These presses are designed for cutting, drawing, and stamping a large number of small shells at each stroke. They are equipped with several types of automatic feeds and operate very rapidly. Such presses are generally used for the manufacture of bottle caps and similar articles, when a large output is necessary. One

type is provided with an automatic chain-feed, stripper, and an automatic sweep for the discharge of shells, and produces fourteen shells per stroke. It will handle sheets of decorative stock in such a way that the printed pattern will register accurately with the dies. The sheet is placed on the feed table, is automatically gripped, carried to the dies, and the bottle caps and scrap are automatically discharged separately.

GANTRY CRANE. This is a crane similar to a traveling crane except that the over-head bridge is carried at each end by a trestle which itself travels on longitudinal tracks on the ground. A trolley on the bridge provides for the transverse motion. Gantry cranes erected in shop yards alongside of a building are sometimes supported by an over-head rail at the end of the bridge next to the building and on a trestle traveling on the ground at the other end.

GANTT BONUS SYSTEM. This is a method of wage payment in which the workman receives his regular daily wage irrespective of the amount of work done and, in addition he receives a bonus which is some percentage of his hourly rate, if he performs a given job in a predetermined time. See Bonus Wage System.

GAP PRESSES. This type of power press is built with a gap or throat through the frame so that the stock can be fed from side to side or from front to back. With the exception of the gap, this type of press is similar to straight-sided or double-crank presses.

GARNET. The garnet is a natural abrasive that is extensively used in woodworking industries, in the manufacture of leather goods, and for other purposes. It is a mineral that varies widely in chemical composition and color. The variety most commonly used as an abrasive is known as "almandite," which is of a deep-red color. This color, however, changes as the material is broken into smaller particles, becoming lighter. Most of the garnet used for abrasive purposes in the United States is obtained in New York state. The almandite garnet is found in the form of crystals in a gangue rock, from which it is separated by crushing and concentrating mechanically in a device known as a jig concentrator.

The hardness of garnet, according to Mohs hardness scale, is about 7. According to this same scale, the diamond, which is the hardest substance, is represented by 10, while talc, which is the softest mineral, is represented by 1. Garnet seems to possess just the right degree of strength, hardness, and brittleness for cutting wood fiber and producing a smooth finish. Its brittleness insures new cutting edges being constantly presented to the work, and the cutting edges remain sharp, owing to its degree of hardness. As garnet has a low point of fusion, it is impossible to bond it in the form of wheels, except by using vegetable and silicate of soda bonds.

GAS ABSORPTION BY LIQUIDS. Many liquids have a capacity for absorbing a certain amount of gas. The quantity thus absorbed varies with the liquid and the gas. Many gases, for example, are readily absorbed by water; thus, water will absorb its own volume of carbonic-acid gas, over two times its volume of chlorine, and 430 times its volume of ammonia. Water will not, however, absorb more than 5 per cent of its volume of oxygen. The weight of gas that a given volume of liquid will absorb is proportionate to the pressure, but as the volume of a given mass of gas is proportionately less as the pressure increases, the volume which a given amount of liquid will absorb at a certain temperature is constant, whatever the pressure. Water absorbs its own volume of carbonic-acid gas at atmospheric pressure. If the pressure is doubled on both the gas and water, the latter will still absorb its own volume of the gas under the higher pressure, but, in that case, the density of the gas is doubled and, consequently, double the weight of the gas is dissolved. The quantity of gas absorbed increases as the temperature is lowered. One of the most important instances of the absorption of gases by liquids is met with in the absorption of acetylene by acetone; the latter liquid absorbs, at 60 degrees F. and 180 pounds pressure per square inch, 300 volumes of acetylene gas. This property of acetone makes it possible to safely store and transport acetylene gas in steel containers.

GAS AND COAL FUEL-OIL EQUIVALENTS. See Fuel Oil, Coal and Gas Equivalents.

GAS AND OIL ENGINES. See Internal Combustion Engines.

GAS CASEHARDENING PROCESS. See Nitrogen Hardening.

GAS COKE. Gas coke is obtained as a by-product in gas works. This coke is produced rapidly at a low heat; it is of a dull black color and ignites readily.

GAS FURNACE FUEL. Gas-fired furnaces use either natural, artificial, or producer gas. Some gas furnaces are equipped with an automatic apparatus which operates in conjunction with a pyrometer for controlling the temperature to within a few degrees of a given point. The air supply is generally obtained from a positive blower, although when a compressor is installed, for operating pneumatic tools, the air is sometimes utilized for the furnaces by interposing reducing valves to diminish the pressure. Artificial gas is more expensive than oil, but is cleaner, and the installation of supply tanks, such as are required for oil, is avoided. Producer gas obtained from a separate plant is not economical unless there is a considerable number of furnaces; in that case, however, it may be the cheapest fuel obtainable. When oxidation or the formation of scale is particularly

objectionable, furnaces of the muffle type are often used, having a refractory retort in which the steel is placed so as to exclude the products of combustion. These muffles must be replaced very frequently and more fuel is required than when an oven type of furnace is used.

GAS, HELIUM. See Helium Gas.

GASHING. The term "gashing" is used especially with relation to the cutting of the teeth in worm-gears. In this operation, a milling cutter is employed having approximately the outline of a normal cross-section of the teeth of the worm. Gashing is simply a roughing process preparatory to *hobbing* the gear teeth. After the gashing operation, the teeth are finished to conform to the exact shape of the worm by revolving the blank in unison with a cutter known as a *hob*, and which is practically a duplicate of the worm, but fluted and relieved so as to provide cutting teeth.

This preliminary gashing operation is done when worm-gears are cut on ordinary milling machines but it is not required when using machines especially adapted for worm-gear cutting.

GASKETS FOR JOINTS. A gasket may be defined as a ring of some compressible material, inserted between two metallic surfaces which are to be tight against leakage of water, steam, or other liquid or gaseous fluid. The gasket forms a loose compressible film between the elements of the joint and, in this way, makes the joint leak-proof. Gaskets are usually made of sheet rubber (or rubber in combination with some other substance, such as asbestos or graphite), sheet copper, sheet lead, cork, and paper. When the steam pressures are comparatively high, ordinary rubber gaskets are liable to be injured by the heat and, in such cases, copper or lead is frequently used. Gaskets containing rubber should not be used in the joints of gasoline engines or in gasoline supply piping, because rubber is slightly soluble in gasoline. For pipes which convey gasoline, it is better to use unions which have ground joints instead of joints made by gaskets. Gasket material composed largely of brass wire gauze and asbestos is frequently used, and, if properly fitted and provided with graphite facing, such gaskets are very durable.

GASOLINE. Most of the gasoline on the market at the present time (70 to 75%) is the natural product distilled from crude oil. Gasoline may also be obtained from the light hydrocarbons by the pyrogenic decomposition of heavy petroleum residue. The so-called casing-head gasoline is a condensate from natural gas. This is always incorporated with heavy hydrocarbons such as naptha, or with gasoline distilled from a heavy crude oil, or with gasoline obtained by a cracking process. Gasoline should have a low end boiling point and a low initial boiling point. The general

refineries' practice is to call everything gasoline which distills up to a temperature of 410 degrees F. The specific gravity may vary from 54 degrees Baumé for heavy crude oils up to 61 degrees for unusually light crude oil. A heavy gasoline must be blended to make it satisfactory for general use. The initial boiling point of ordinary commercial gasoline varies from 80 degrees F. to 160 degrees F.; the end boiling point, from 368 degrees F. to 450 degrees F., and the specific gravity from 56 degrees to 61 degrees Baumé. Gasoline contains 129,060 British thermal units per gallon, or 20,750 per pound. The freezing temperature is 50 degrees F. below zero. Gasoline readily vaporizes when exposed to the air of any temperature down to 15 degrees F. below zero. The vapor is nearly three times as heavy as air, and when mixed with the proper quantity of air becomes violently explosive. If confined where there is poor ventilation, this mixture will sometimes remain in the explosive condition for several months. The vapor will ignite from an open flame, a spark from a grinding wheel or from a sufficiently heated surface.

GASOLINE CRACKING PROCESS. See Cracking Process.

GAS PRODUCERS. The gas producer is an apparatus for the manufacture of combustible gas from solid fuel. Briefly described, it consists of a space enclosed by refractory materials and containing solid fuel (coal, coke, wood, or peat) at a high temperature, through which air and steam are caused to pass. The reaction between the air and steam and the fuel, which latter consists largely of carbon, causes the formation of hydrogen and carbon monoxide. These two combustible gases, mixed with the inert nitrogen introduced by the air, form a gas known as "producer gas."

Gas producers are classified as "pressure producers" and "suction producers." In pressure producers, the air and steam are introduced into the producer at a pressure greater than that of the atmosphere, and the gas leaves the producer at a pressure slightly above the pressure of the outside air. In the suction producer, the air and steam are drawn into the producer by creating a partial vacuum in it, and the gas leaves the producer at a pressure lower than that of the atmosphere. Generally speaking, pressure producers are commonly used in metallurgical work, where the gas is employed for heating furnaces, since it is easier to handle and transmit the gas when it is at a pressure slightly above, rather than below, that of the atmosphere. Suction producers are used principally for furnishing the fuel gas for gas engines, because the gas is cleaner; the suction of the engine piston furnishes the necessary partial vacuum required for drawing from the producer the quantity of gas needed for the engine. The commercial designs of producers may be classified as five distinct types: The up-draft pressure type; the down-draft pressure type; the up-draft suc-

tion type; the down-draft suction type; and the combined up-and-down-draft suction type.

GAS PRODUCTION. Manufactured gas may either be coal gas, water gas or oil gas. In producing *coal gas* certain kinds of bituminous coals are distilled in retorts or ovens and the resulting gases are condensed, scrubbed, washed and purified to remove water vapor, tar, ammonia and sulphur. *Water gas* is produced by an intermittent process in which a bed of anthracite coal or coke is raised to a high temperature by an air blast and then steam under pressure is blown through the fuel, forming carbon monoxide, hydrogen and a small amount of carbon dioxide by reaction with the carbon in the fuel. The so-called *blue water gas* thus obtained has a heating value of about 300 B.T.U. per cubic foot and almost no luminosity when burned in an open flame. "Mixed gas" is usually understood to be a mixture of carbureted water gas and coal or coke-oven gas, and it is supplied in many cities in the United States where requirements permit. Where oil is cheap and coal expensive, as on the Pacific Coast, oil gas is produced as it is more economical than the coal or water gases. In making oil gas, oil alone is used as fuel.

Natural Gas. — Natural gas usually is associated with deposits of coal or petroleum and it is found trapped in various strata of the earth, principally in loose sandstone formations or in shale seams and cavities. Ordinarily natural gas is associated with petroleum and occupies the space above the oil in the petroleum-bearing sand. Occasionally gas is not accompanied by oil, in which case the gas composition is somewhat different.

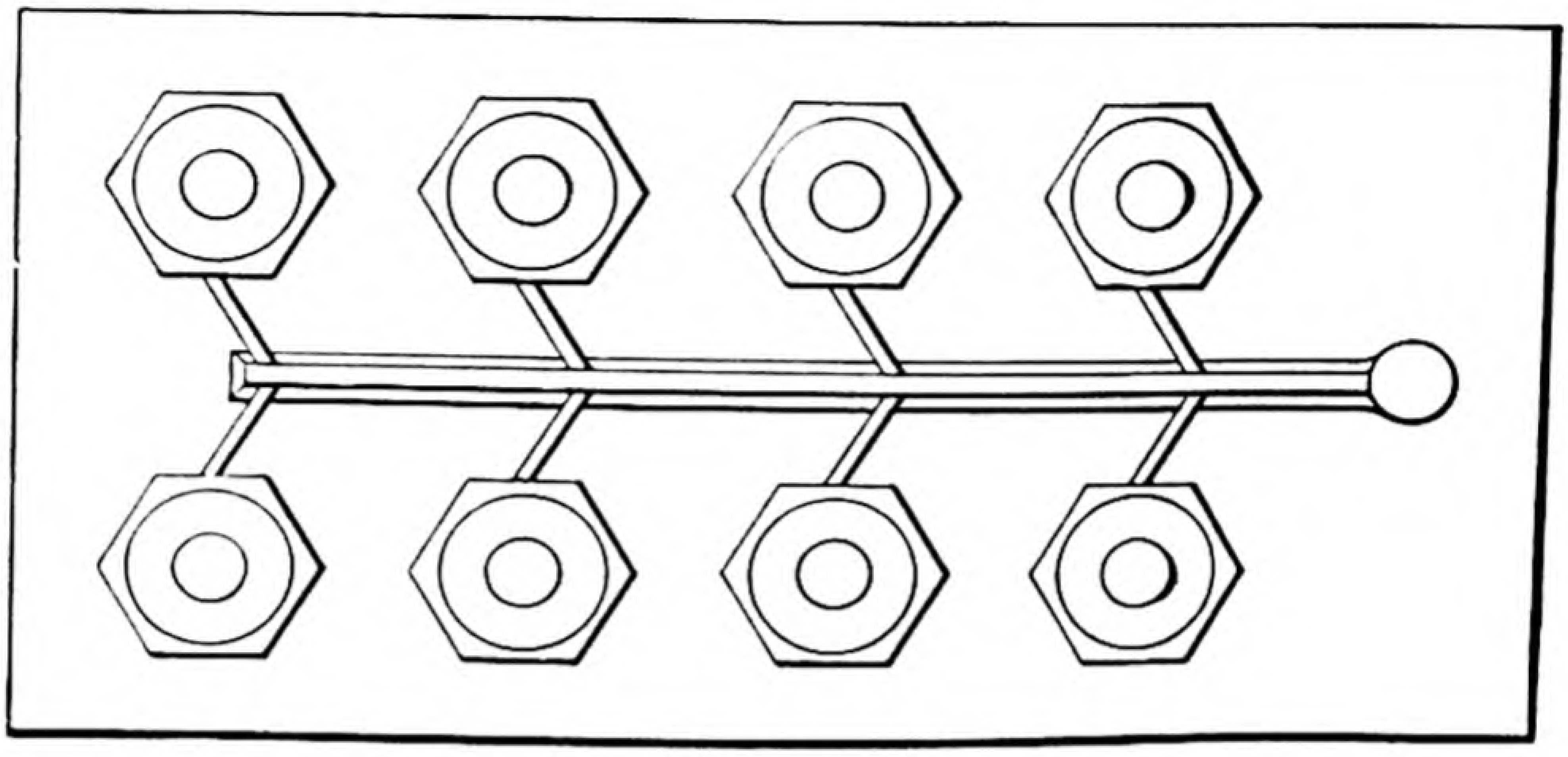
GAS PYROMETERS. In gas pyrometers, the change in pressure of a gaseous mass kept at a constant volume is used to indicate the temperature. Pyrometers based on this principle occupy considerable space and are not suitable for ordinary practical work. They are used only for standardizing other pyrometers.

GAS TURBINE. A gas turbine is a rotary prime mover or power-producing machine in which the combustion gases of an explosive mixture of gas and air impinge at high pressure upon the blades of a turbine wheel or rotor in a manner similar to that in which steam impinges upon the blades of a steam turbine. A number of experimental designs have been constructed.

GAS WELDING. See Oxy-acetylene Welding.

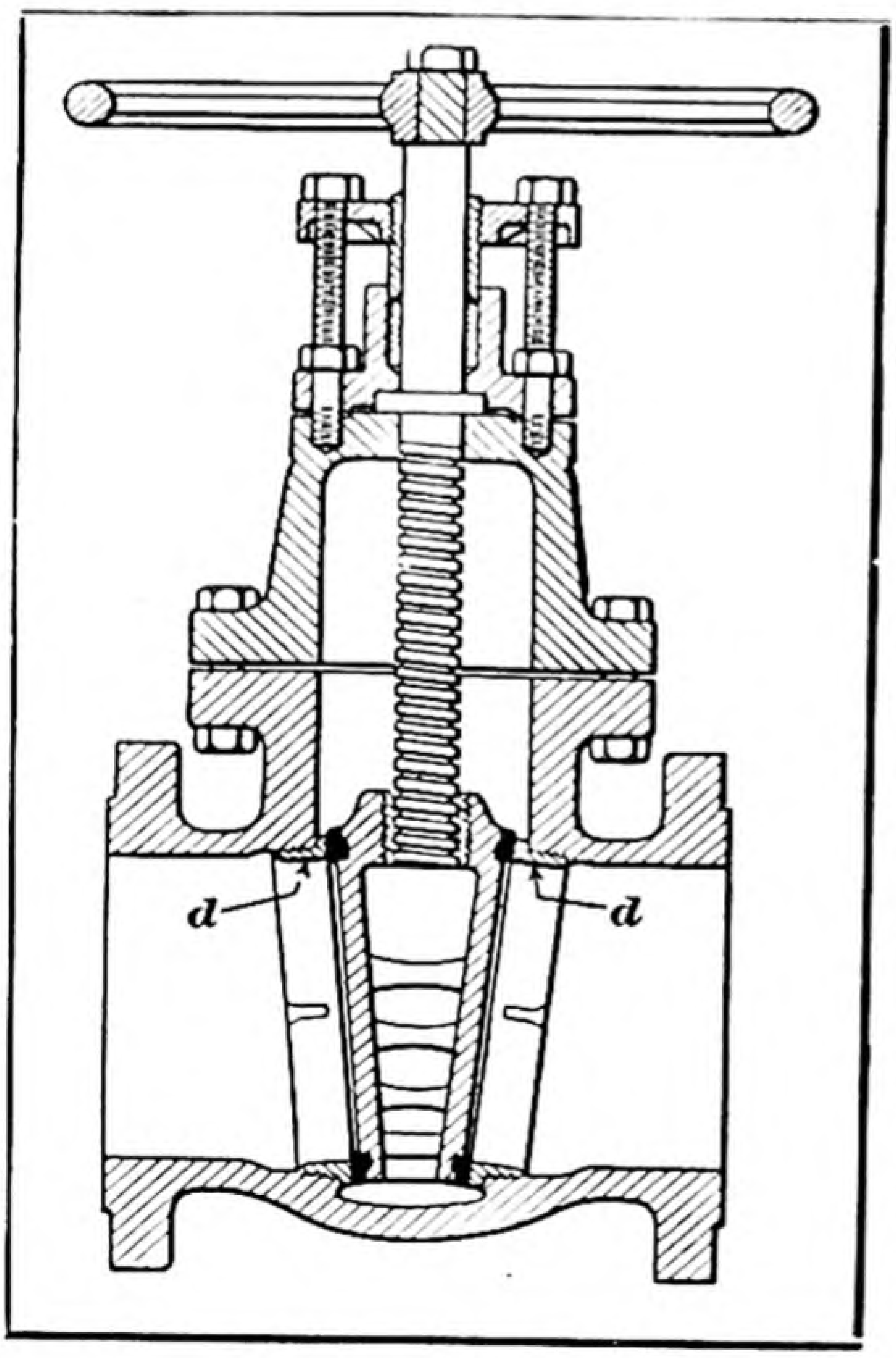
GATED PATTERNS. Where large numbers of small castings are required, it is more economical to make metal patterns and mount them on a gate. This means that a number of patterns are fastened to a pattern that forms the opening for pouring the metal and the channels for con-

veying it to the individual molds. The illustration shows a "gate" of hexagon nuts.



Gate of Hexagon Nuts

GATE VALVES. A gate valve, as its name implies, is constructed on the principle of a gate, which is raised or lowered by the action of a screw or other mechanical means. Several forms of gate valves are used; some close the valve opening with a box wedge, others with sectional gates having seats parallel or wedge-shaped, and still others with gates formed like a solid wedge. One of the principal advantages in the use of a gate valve is that the opening is such that it does not obstruct the flow of liquid to any great extent. Valves of this kind are particularly desirable when the resistance to the flow of liquid should be as small as possible. Some gate valves are so made that the stem which raises the valve is threaded at its upper end, and passes up through the hub of the handwheel. In the form shown (see illustration), the stem is threaded at its lower end and enters a nut in the upper part of the wedge-shaped valve gate. The seat in the body of the valve is formed by rings which are inserted in both the gate and body, as indicated at *d* in the illustration.



Gate Valve

These rings are in each case made of soft metal, and are firmly imbedded and then faced off in such a way that the tapers coincide.

GAYLEY'S DRY BLAST. This is a process used in connection with blast furnaces by which the moisture is removed from the air before it is forced into the furnace, thus greatly increasing the heat produced in the smelting zone and permitting the use of less fuel.

GEAR, BASE CIRCLE. See Base Circle of a Gear.

GEAR CASTINGS, BRONZE. The following recommended practice for bronze and brass castings for gears, has been approved by the American Gear Manufacturers' Association.

For *spur and bevel gears*, use the hard cast bronze S.A.E. No. 62 or the well-known 88-10-2 mixture, keeping within the following limits: Copper, 86 to 89 per cent; tin, 9 to 11 per cent; zinc, 1 to 3 per cent; lead (maximum), 0.20 per cent; iron (maximum), 0.06 per cent. Good castings made from this bronze should give the following minimum physical characteristics: Ultimate strength, 30,000 pounds per square inch; yield point, 15,000 pounds per square inch; elongation in 2 inches, 14 per cent.

For *bronze worm-gears*, two alternative analyses of phosphor-bronze are recommended, namely, S.A.E. No. 65 and No. 63. The S.A.E. No. 65, called phosphor-gear bronze, has the following composition: Copper, 88 to 90 per cent; tin, 10 to 12 per cent; phosphorus, 0.1 to 0.3 per cent; lead, zinc, and impurities (maximum), 0.5 per cent. Good castings made from this alloy should give the following minimum physical characteristics: Ultimate strength, 35,000 pounds per square inch; yield point, 20,000 pounds per square inch; elongation in 2 inches, 10 per cent.

Composition for the S.A.E. No. 63 alloy, called leaded gun metal, is: Copper, 86 to 89 per cent; tin, 9 to 11 per cent; lead, 1 to 2.5 per cent; phosphorus (maximum), 0.25 per cent; zinc and impurities (maximum), 0.50 per cent. Good castings made of this alloy should give the following minimum physical characteristics: Ultimate strength, 30,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches, 10 per cent.

These alloys, especially No. 65, can be chilled for increasing the hardness and refining the grain. No. 65 is to be preferred for use with worms of great hardness and fine accuracy. No. 63 is to be preferred for use with unhardened worms.

For bronze *bushings for gears*, S.A.E. No. 64 is recommended, having the following analysis: Copper, 78.5 to 81.5 per cent; tin, 9 to 11 per cent; lead, 9 to 11 per cent; phosphorus, 0.05 to 0.25 per cent; zinc (maximum), 0.75 per cent; other impurities (maximum), 0.25 per cent. Good castings of this alloy should give the following minimum physical characteristics:

Ultimate strength, 25,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in 2 inches, 8 per cent. See English Gear Bronze; also Phosphor-Bronze.

GEAR-CHUCKING METHODS. The following methods are employed for holding gears while grinding the shaft holes: (1) Holding the gear by the outside diameter or tops of the teeth. (2) Using rolls between the teeth — sometimes called the "pitch-line control method." (3) Using jaws of special shape, which make contact with the gear at the bottom of the tooth spaces — a method known as "root control." The first method cannot be used with success when the gears are to run at high speeds, because of the possible lack of concentricity between the hole and the working surfaces of the teeth. The second method, while requiring the use of a more expensive chuck, is much more satisfactory than the first, provided the spacing of the teeth has not been affected by hardening and the rolls are uniform in diameter and supported by a truly concentric surface. A slight variation in the width of the tooth spaces, however, makes a considerable difference in the relative position of the rolls, owing to the acute angle made by the tooth surfaces near the pitch line where the rolls bear. This has been considered, by some manufacturers, a serious objection to this method. For the average line of work, the third method is recommended. The jaws of the chuck engage the bottom of the tooth spaces, so that inaccuracies of spacing, due to hardening the teeth, do not affect the accurate holding of the gear; furthermore, it is a very simple matter to maintain the accuracy of the jaws by simply truing the contact points whenever necessary.

GEAR-CUTTERS. The series of formed cutters for cutting *involute* gear teeth, adopted by the Brown & Sharpe Mfg. Co., contains eight cutters for each pitch. These eight cutters are adapted to cut all gearing from a pinion of twelve teeth to a rack. Each cutter may be used for a limited range of tooth numbers. The number of teeth and the pitch for which a cutter is adapted are always marked on the cutter. These cutters are numbered from 1 to 8 and the different numbers are adapted for spur gears of the following sizes: Cutter No. 1, for gears having teeth varying from 135 to a rack; No. 2, gears with from 55 to 134 teeth; No. 3, from 35 to 54 teeth; No. 4, from 26 to 34 teeth; No. 5, from 21 to 25 teeth; No. 6, from 17 to 20 teeth; No. 7, from 14 to 16 teeth; and No. 8, from 12 to 13 teeth. If it is assumed that the diametral pitch of the gear to be cut is 12, and the required number of teeth, 90, a No. 2 cutter of 12 diametral pitch would be used, the No. 2 shape being selected because it is intended for all gears having teeth varying from 55 to 134.

When greater accuracy of tooth shape is desired to insure smoother or

quieter operation, an intermediate series of cutters having half numbers is used. The half numbered cutters made by the Brown & Sharpe Mfg. Co., are for the following ranges of tooth numbers: Cutter No. $1\frac{1}{2}$, 80 to 134 teeth; No. $2\frac{1}{2}$, 42 to 54; No. $3\frac{1}{2}$, 30 to 34; No. $4\frac{1}{2}$, 23 to 25; No. $5\frac{1}{2}$, 19 and 20; No. $6\frac{1}{2}$, 15 and 16; and No. $7\frac{1}{2}$, 13 teeth. There are seven cutters in this series, No. $8\frac{1}{2}$ being omitted since this would be for a pinion with less than 12 teeth.

GEAR-CUTTING ATTACHMENT. When it is necessary to cut comparatively large spur gears on a milling machine, a gear-cutting attachment is preferable to the regular dividing-head. This attachment, in its usual form, is similar to a dividing-head, but is larger and heavier in construction. If the gear is too large to clear the machine table when mounted between the centers, the centers are sometimes raised far enough to provide clearance for the gear blank by placing parallel blocks underneath the index-head and tail-center. If the gear blank is so large that it will not pass under the cutter arbor with the table in its lowest position, it may be possible to cut the gear by using an "under-cutting attachment." The centers are raised far enough to provide room for the cutter beneath the gear, and the arbor is supported by a special outboard bearing.

GEAR-CUTTING PROCESSES. The gear-cutting processes commonly utilized for producing different types of gears may be divided into three general classes. One includes the use of tools or cutters which form gear teeth by reproducing the shape of the cutter itself; in another class are the generating processes whereby the proper tooth curves are formed through relative motions of the tool and work, as when a straight-sided cutting tool generates the required tooth curves due to the relative motions imparted to the gear blank and cutter. The third general classification includes the use of templets or master formers, which control the path followed by the cutting tool, and consequently the curvature of the gear tooth; this method is applied chiefly to the cutting of very large gears.

In the application of these processes the gear teeth may be formed by (1) milling the teeth with cutters conforming to the shape of the spaces between the teeth; (2) milling the teeth with a cutter of the hob type, which represents a rack in the axial plane and is used in generating the tooth curves; (3) planing with a circular cutter which has teeth like a gear and serves to generate the tooth curves as the cutter and gear blank revolve in unison; (4) planing with a tool that takes a series of cuts across the side of the tooth and is guided by a templet or former as it is gradually fed inward; (5) planing with a tool that conforms to a single rack tooth and generates the tooth curves as it moves laterally after each stroke, while the gear blank receives an indexing movement that causes each tooth

to mesh properly with the traversing tool; (6) planing with a tool which is similar to a short section of a rack and is used in generating tooth curves as the gear blank rotates relative to the rack cutter; and (7) planing the teeth of the gear by the use of a formed tool which is of the same shape as the tooth spaces. See following paragraphs on gear-cutting processes and machines; also Automatic Gear-cutting Machines; Bevel Gear Generating Processes; Hobbing Process.

GEAR GENERATING. In order to illustrate the principle of the generating process of gear-cutting, assume that a finished spur gear having teeth of correct form is revolved while in contact with a blank, which for purposes of illustration is assumed to be made of some soft, plastic material. The nature of this rolling action would be to generate teeth on the plastic blank. Thus, the teeth on the finished gear, as they roll into contact with the blank, form teeth having the curvature required for meshing properly with the generating teeth. Now, if this tooth forming or generating gear were hardened, and its teeth given suitable clearance, the cutter thus formed could be used to generate teeth in a cast-iron or steel blank, provided the cutter had a reciprocating action parallel to the axis of the blank, whiie both cutter and blank slowly revolved together, the same as two gears in mesh. This method of using a gear-shaped cutter is employed on a well-known type of machine.

Another method of generating gear teeth is to give the gear blank a rolling movement relative to a rack-shaped cutter. It is possible to employ either a gear-shaped or a rack-shaped cutter, because a rack can be designed, for any system of interchangeable gearing, which will mesh correctly with a range of gear sizes of the same pitch. Moreover, all gears that will mesh properly with the rack will also mesh with one another. Generating processes of cutting gears are based on this interchangeable feature, which also accounts for the fact that one cutter may be used for cutting various sizes of gears of the same pitch. The cutter represents either a rack or a gear of the interchangeable series, and it cuts or generates teeth as the uncut gear blank and cutter are given movements, relative to each other, similar to a finished gear running in mesh either with a rack or with another gear, depending upon the type of cutter that is used. See also Bevel Gear Generating Processes.

GEAR-HOBBING MACHINES. Gear-hobbing machines are commonly applied to the cutting of spur, helical, and worm gearing. In the practical application of the generating principle to gear-hobbing machines, the hob used has cutting teeth of the same cross-sectional shape as teeth of a rack of corresponding pitch, except for minor variations such, for example, as increasing the length of the hob teeth to provide for clearance

at the bottom of the tooth spaces. As the hob teeth lie along a helical path (like a screw thread) the hob is set at an angle to align the teeth on the cutting side with the axis of the gear blank. When the hob is inclined an amount depending upon its helix angle the teeth on the cutting side represent a rack.

When a hobbing machine is in operation, the gear blank and hob revolve together, the ratio depending upon the number of teeth in the gear and the number of threads on the hob — that is, whether the hob has a single or a multiple thread. This rotation of the hob causes successive teeth to occupy positions corresponding to the teeth of a rack, assuming that the latter were in mesh with the revolving gear and moving tangentially. In conjunction with the rotary movement of the hob, the slide on which it is carried is given a feeding movement parallel to the axis of the gear blank.

GEAR PLANERS OF TEMPLET TYPE. Large spur gears of coarse pitch may be cut either by planing on a templet or form-copying type of machine, by milling with a formed cutter, or by hobbing. Most gear manufacturers use the templet planer for the very large gears. One advantage of this type of machine is that simple, inexpensive tools are used, and this is very important, as often only one of these large gears is required, and the cost of making a formed cutter or hob would be prohibitive. Gear-cutting machines of the templet type are also used for cutting large spur, bevel, and herring-bone gears; in fact, gear planers of this class are used invariably for cutting very large bevel gears. Some gear planers are designed for cutting spur gears exclusively, but there are also combination types which may be applied to either spur or bevel gears.

A characteristic feature of the templet planer is the templet or master former which serves to guide the planing tool, thus causing it to plane teeth having the correct shape or curvature. When the planer is at work, a slide or head which carries the tool is given a reciprocating motion, and as the tool feeds inward for each stroke, the path it follows is controlled by the templet. The traversing movement of the tool-slide is derived from a crank on some gear planers, whereas others have a reversing screw. Still another method of traversing the head is by means of a rack and pinion, the latter being arranged to rotate in opposite directions.

GEAR SHAPER. The Fellows gear shaper is a machine of the generating type which operates with a shaping or planing action to generate gear teeth. The cutter has tooth outlines conforming to a gear of the same pitch as the ones being cut. This cutter is reciprocated vertically, and in starting to cut a gear it is first fed in to depth; then one gear tooth after another is formed as cutter and work slowly rotate together just as though two finished gears were in mesh. The gear blank is withdrawn

from the cutter upon the return stroke to prevent dragging, the work-arbor being held by an apron actuated by a relieving mechanism. The gear teeth can be finished in one revolution of the gear blank, although a light finishing cut is often taken. In cutting transmission gears for automobiles, it is common practice to take a roughing cut followed by a light finishing cut. The machine may be arranged to take these two cuts automatically, but when gears are required on a large scale, it is generally considered preferable to use certain machines for roughing and others for finishing.

GEARS, NON-METALLIC. Non-metallic gears are used primarily where quietness of operation at high speed is the first consideration. Raw-hide was the earliest material used for this class of gearing; later numerous other materials such as micarta, formica, condensite, fabrico, fabroil, and Egyptian fiber were introduced. These materials are used by many gear manufacturers when the gears are not subjected to severe stresses.

GEARS, RATIOS IN SPEED-CHANGING MECHANISMS. See under Speed-changing Mechanisms.

GEAR STEELS. There are two distinct types of gear steels, one of which may be termed a carburizing or casehardening steel and the other a hardening steel or one having enough carbon to harden by quenching. The difference in the composition of the two types of steel is entirely in the carbon content, the carbon never being higher than 0.25 per cent in the carburizing type, while in the hardening steel it is seldom lower than 0.35 per cent. The difference in the completed gear is in the hardness. The carburized gear is file hard on the surface, with a soft, tough, and ductile core, which withstands shocks, while the hardened gear has a surface that can be touched with a file, but has a core of the same hardness as the outer surface.

With the exception of some of the higher grades of alloy steels, where the percentages of special elements, such as nickel and chromium, are quite high, which causes a slight air-hardening action, the carburizing steels are soft enough for machining when air-cooled from any temperature, including the temperature at which gear blanks are finished at the hammer. This condition has led many drop-forging and manufacturing concerns to believe that the annealing of the blanks involves an unnecessary expense, and often the blanks are only heated to a low temperature, many times just until color begins to show, to relieve the so-called "hammer-strains." While this is only a compromise, it is better than no reheating at all, although it does not properly refine the grain of the blank to insure good machining conditions.

Of the alloy casehardening steels, three principal grades of nickel steel

have been used. These are 5-per-cent open-hearth nickel alloy; $3\frac{1}{2}$-per-cent open hearth nickel; and from 1- to $1\frac{1}{2}$-per-cent nickel natural alloy. The principal characteristics of these steels are a higher tensile strength than straight-carbon steel, and a correspondingly higher strength after casehardening. Unlike casehardened gears, hardened high-carbon gears are of uniform carbon content throughout, and, when hardened, have a uniform hardness throughout the tooth section. Common steels used for these gears are of three general classes: 1. Silico-manganese. 2. Chrome-vanadium. 3. Chrome-nickel steel. The last-named is the most used. The carbon content varies for the different classes from 0.40 to 0.60 per cent.

GEAR STEELS, A.G.M.A. The recommended practice for forged and rolled carbon steel gears, details of which are given in the following, has been approved by the American Gear Manufacturers' Association and the American Society of Mechanical Engineers. This specification covers steel for gears in three groups, according to heat-treatment, as follows: (*a*) casehardened gears; (*b*) unhardened gears, not heat-treated after machining; and (*c*) hardened and tempered gears.

Forged or rolled gear steels shall be purchased on the basis of the requirements as to chemical composition specified in the accompanying table. Requirements as to physical properties have been omitted, but when they are given, requirements as to carbon content shall be omitted. The steels may be made by either the open-hearth or electric furnace process. A sufficient discard shall be made from each ingot to secure freedom from injurious piping and undue segregation.

Chemical Composition for Forged and Rolled Carbon Steel for Gears.

Use	Class	Carbon	Manganese	Phosphorus	Sulphur
Casehardened......	C	0.15 to 0.25	0.40 to 0.60	Max. 0.045	Max. 0.05
Untreated*.........	N	0.25 to 0.50	0.50 to 0.80	Max. 0.045	Max. 0.05
		0.40 to 0.50	0.40 to 0.60	Max. 0.045	Max. 0.05
Hardened..........	H	0.40 to 0.50	0.40 to 0.60	Max. 0.045	Max. 0.05

* Class N steel will normally be ordered in 10-point carbon ranges within these limits.

Ladle and Check Analyses. — An analysis of each melt of steel shall be made by the manufacturer to determine the percentages of the elements specified. This analysis shall be made from drillings taken at least $\frac{1}{4}$ inch beneath the surface of a test ingot obtained during the pouring of the melt. The chemical composition thus determined shall be reported to the purchaser or his representative, and shall conform to the requirements specified.

Analyses may be made by the purchaser from one or more bars or forgings representing each melt. The chemical composition thus determined shall conform to the requirements specified in the table. Drillings for analysis shall be taken at any point not closer to the center than midway between the center and the surface, but not within ¼ inch of the surface of the bar or forging. Users requiring a 0.45 per cent carbon steel to withstand a drastic quench may add the following sentence, which is not a part of the general specifications: "In class H only, the combined manganese and carbon shall lie between a lower limit of 0.85 per cent and an upper limit of 1.05 per cent."

GEARS, TYPES. See Bevel Gear; Bevel Gears, Gleason System; Friction Gearing; Helical Gears; Herringbone Gears; Internal Gears; Maag Gearing; Spur Gearing.

GEAR TEETH. See Cycloidal Gear Teeth; also Involute Gear Teeth.

GEAR TEETH, BURNISHING. See Burnishing Gear Teeth.

GEAR TEETH INVENTION. The invention of gear teeth cannot be credited to any one man, as their development represents a gradual evolution from gearing of primitive form. Gears were known to Archimedes who lived 287–212 B.C., according to Ctesibius of Alexandria in his "History of Mathematics." Ctesibius first applied gears to the clepsydrae (water clocks) about 150 B.C. The knowledge and use of toothed wheels by the Romans early in the Christian era is indicated by the fact that they are shown sculptured on the Column of Trajan in Rome. Leonardo da Vinci, showed an appreciation of the use of gearing, many applications of it in connection with mechanisms devised for widely varying purposes being found in the sketches that form a part of his "Codice Atlantico." This work illustrates the use of worm-gearing, and suggests a choice of two forms of teeth, one of the buttress type and the other in shape much like present-day practice.

The Cycloidal Form. — The earliest evidence we have of an investigation of the problem of uniform motion for toothed gearing and the successful solution of that problem, dates from the time of Olaf Roemer, the celebrated Danish astronomer, who, in the year 1674, proposed the epicycloidal form to obtain uniform motion in trains of gearing. In 1766 Charles E. L. Camus, in his treatise "Cours de Mathematique," dealt with gearing. This treatise fully describes the epicycloidal curve in such a way as to make it for the first time available to some extent for practical application, and points out its advantages as applied to gearing. Camus deals only with the epicycloidal form of tooth, and emphasizes its application to clock and watch work. Evidently Robert Willis, professor in the University of

Cambridge, was the first to make a practical application of the epicycloidal curve so as to provide for an interchangeable series of gears. Willis gives credit to Camus for conceiving the idea of interchangeable gears, but claims for himself its first application.

The Involute Form. — The involute tooth was suggested as a theory by early scientists and mathematicians, but it remained for Willis to present it in a practical form for use by the manufacturing public. Perhaps the earliest conception of the application of this form of teeth to gears was by Philippe de Lahire, a Frenchman, who considered it, in theory, equally suitable with the epicycloidal for tooth outlines. This was about 1695 and not long after Roemer had first demonstrated the epicycloidal form. The applicability of the involute had been further elucidated by Leonard Euler, a Swiss mathematician, born at Basel, 1707, who is credited by Willis with being the first to suggest it. Willis devised the Willis odontograph for laying out involute teeth.

Selection of Pressure Angle. — A pressure angle of $14\frac{1}{2}$ degrees was selected for three different reasons. First, because the sine of $14\frac{1}{2}$ degrees is nearly $\frac{1}{4}$, making it convenient in calculation; second, because this angle coincides closely with the pressure angle resulting from the usual construction of epicycloidal gear teeth; third, because the sides of worm threads incline $14\frac{1}{2}$ degrees, so that the straight-sided involute rack has the same angle as the worm thread.

The Formed Cutter. — The invention of the formed cutter by Joseph R. Brown in 1864 made possible the use of accurately cut gearing and proved to be an important element in the introduction of the interchangeable system of involute gears.

GEAR-TOOTH CALIPER. A vernier gear tooth caliper is used to measure the *chordal* thickness of a gear tooth. This chordal thickness, which is slightly less than one-half the circular pitch, may be determined as follows: First divide 90 degrees by the number of teeth in the gear, and then find the sine of the angle thus obtained. Next, multiply this sine by the pitch diameter; the product equals the chordal thickness. Before measuring the chordal thickness, it is necessary to set the vertical scale of the vernier gear tooth caliper so that the caliper jaws come into contact with the sides of the tooth at the pitch circle. To determine this vertical adjustment or "corrected addendum" the cosine of the angle equal to 90 degrees divided by the number of teeth, is first subtracted from 1; this difference is then multiplied by the pitch radius of the gear and the product is added to the addendum of the tooth. This final result equals the corrected addendum or the dimension to which the vertical scale of the gear tooth caliper should be set.

GEAR-TOOTH CHAMFERING. Many geared speed-changing mechanisms are so designed that speed variations are obtained by means of sliding gears which are shifted so as to mesh with gears of different sizes. In order to facilitate the engagement of these " class gears," as they are sometimes called, the ends of the teeth are chamfered or rounded. Special machines have been designed for chamfering the ends of gear teeth.

GEAR-TOOTH COMPARATOR. The Sykes gear-tooth comparator consists of a frame carrying one fixed and one adjustable jaw, in addition to a specially designed dial test indicator. The movable jaw is provided with means for fine adjustment, and between the jaws the plunger of the dial indicator projects. The instrument is set to a master gage block. Each gage block represents an involute rack tooth of a particular pitch and pressure angle, and the inclined faces of the jaws are made to correspond. Instead of gage blocks a master gear may be used. It is well known that any gear, irrespective of the number of teeth, will mesh accurately with a basic rack. Therefore, when the comparator is set for a rack tooth (represented by the gage block) it is correct for all teeth of the same thickness, pressure angle, and addendum. Any tooth thicker or thinner than that to which the instrument is set will cause the dial indicator to show plus or minus, owing to the height to which the tooth rises between the jaws. When the instrument is only needed for testing uniformity of teeth, gage blocks are not necessary.

GEAR-TOOTH CURVES. In developing or laying out the teeth or spur gearing, the idea is to form the teeth in such a way that the action of the gears will be like plain disks rolling together, the motion being transmitted smoothly and at a uniform rate. Similarly, bevel gearing is intended to reproduce the action of two frustums of cones rolling in contact with each other. There are various curves which might be applied to gear teeth in order to secure rotation between two gears having intermeshing teeth, but the *involute curve* is used almost universally because it has certain practical advantages which account for the fact that it has largely replaced the cycloidal curves formerly employed. See Involute Gear Teeth, Cycloidal Gear Teeth, and Gear-tooth Standards.

GEAR-TOOTH GRINDING. Several types of machines for grinding gear teeth have been developed. These machines are largely used in the automotive field at present, but the indications are that hardened and ground gearing will be utilized on a greatly increasing scale in various branches of the machine-building industry.

Single Wheel Method.—One method of generating tooth curves by grinding is to use the flat face of a wheel which is perpendicular to the wheel axis and inclined from the vertical an amount equal to the pressure angle

of the gear to be ground. In order to generate involute tooth curves, provision must be made for rolling the gear past the revolving grinding wheel, just as though an accurate gear were rolling along an accurate rack having the side of one tooth in the same position as the grinding face of the wheel. A common method of obtaining this rolling or generating motion is by the use of steel tapes in conjunction with a drum or disk having a radius approximately equal to the pitch radius of the gear.

Use of Two Grinding Wheels. — A method of grinding two tooth surfaces at the same time consists in using two wheels which operate in different tooth spaces. The flat side of each wheel corresponds in location to the side of an imaginary rack tooth, and the generating action is the same as though the pitch circle of the gear were rolling along the pitch line of the rack, the motion being the same as with a single wheel.

Rotary Type of Grinder. — A gear tooth grinder that may be designated as a rotary type, is so designed that the gear being ground rotates continuously in one direction and its action is regulated in such a way that all the tooth surfaces are finished without employing an intermittent indexing movement. A master gear and rack mechanism is utilized to control the generating movement and to bring the gear into contact alternately with the two grinding wheels with which the machine is equipped.

Form-wheel Method. — The formed-wheel method is based on the use of a grinding wheel having surfaces that are shaped to conform to the space between correctly formed gear teeth. This method is similar in principle to the use of formed cutters for cutting gear teeth, in that the shape of the grinding wheel is reproduced in the teeth.

Allowance. — Just how much stock must be removed in grinding gear teeth to compensate for the greatest distortion that is likely to occur varies for different gears and frequently is affected by the method of heat-treatment. As a general rule, the removal of 0.003 to 0.005 inch from each tooth face is sufficient to correct all distortion, and in some cases, the removal of only 0.002 inch is sufficient. These allowances are based on the assumption that the machine and cutters used for the preliminary cutting operation are of an approved type and in reasonably good condition.

GEAR-TOOTH STANDARD, AMERICAN. The American Gear Manufacturers' Association and the American Society of Mechanical Engineers, acting as joint sponsors under the procedure of the American Engineering Standards Committee have adopted a standard spur gear tooth form. This standard applies both to the 14½-degree composite system (full-depth tooth) and to the 20-degree stub involute system. The central part of the 14½-degree basic rack for this composite system, is a straight line which inclines 14½ degrees with the vertical, and the upper and lower portions

of the tooth are cycloidal curves. These curves are approximated by arcs having a radius equal to 3.75 divided by the diametral pitch, and they are struck from centers located above and below the pitch line an amount equal to 0.56278 divided by the diametral pitch. The basic rack for the 20-degree stub involute tooth is a straight-line unmodified form.

This composite standard is in response to a desire to have in scientific form the basic rack of the interchangeable system of gearing used for many years in this country and abroad, and usually produced by disk cutters. Gears generated for this rack and produced by any system of good gear cutting, will interchange with each other and with gears made to the $14\frac{1}{2}$-degree system of disk cutters.

It is well known that a straight-sided unmodified basic rack will produce involute gearing, but unless the pressure angle is made much higher than the angles now in use, under-cutting becomes a serious matter on pinions of low numbers of teeth. This interference can be overcome for a single pair of gears by changing diameters and pressure angles, but to have a basic rack that will generate both the gears and pinions for interchangeable purposes, the problem is more complex. This composite standard avoids interference by rounding off the tips or addendums of the teeth, and filling in the roots by modifying the involute curve so that it is continued at the tip and bottom as a cycloid curve, thereby strengthening the roots of the teeth and allowing the teeth to have tooth action beyond that which would be obtained with the pure involute. The line of action is therefore longer with the composite system than with the pure involute; that is, the teeth are in action for a longer period.

GEAR-TOOTH STANDARD, GERMAN. The Committee on Gear Teeth of the N. D. I. (Normenausschuss der Deutschen Industrie), has tentatively adopted a standard for spur gear teeth having the following features.

1. The basic rack is a straight-sided or unmodified involute rack.
2. The pressure angle equals 20 degrees.
3. The total tooth depth equals $2 \times$ circular pitch $\div 3.1416 = 2 \times$ module. (It will be understood that all dimensions are in millimeters.)
4. The tooth thickness and width of the space as measured along the pitch circle are equal.
5. Clearance equals 0.1 to $0.25 \times$ module.
6. Radius of fillet at root of tooth equals $1.5 \times$ clearance.
7. Certain tip and root modifications are admissible to compensate for errors in tooth spacing.

Although the majority of German firms now use $14\frac{1}{2}$-degree and 15-degree angles, gears having a 20-degree angle and normal height of tooth may be produced down to 17 teeth without under-cutting and without resorting

to special methods, such as " profile shifting " or tip and root modification. With a pressure angle of 15 degrees, 30 teeth is the limit for undercutting. The larger pressure angle also gives more favorable values with respect to strength and surface pressure.

The rule for the whole depth of the tooth, which up to the present has been employed largely for 15-degree gears, has also been quite generally approved for the proposed standard. A special standard stub tooth for German manufacturers was not advocated for two reasons: First, if the addendum is made equal to 0.8 times the module instead of making it equal to the module, the amount of overlap and the arc of action will be reduced considerably. Theoretically, the number of teeth in contact might be just above the value 1, but practically, a liberal excess or overlap is required if the sides of the teeth are to be modified to secure smooth quiet running. The second and perhaps more important reason for retaining the full tooth depth is that it presents a larger wearing surface than a stub tooth, and consequently, wear is reduced. This fact has been proved by many experiments conducted by the American standardization committee. It was found that the life of gears having full-depth teeth was considerably longer than those with stub teeth, the results indicating an increase in durability ranging from 300 to 400 per cent.

The tooth thickness and width of the space as measured along the pitch circle are made equal, so that if two gears are located at the standard or normal center-to-center distance, there will be no side play. To obtain the desired side play, therefore, the center-to-center distance has to be increased.

GENELITE. The material called " Genelite," is a high-grade bearing bronze, made synthetically. The novel feature of this material is the admixture of finely divided graphite with the bronze in such a manner that it is uniformly distributed throughout the mass in a volume proportion as high as 40 per cent. This uniform distribution is accomplished by mixing graphite with the powdered oxides (copper, lead, and tin oxides) composing the bronze, in a sufficient quantity to reduce the oxides and leave the desired amount of graphite after the reduction is complete. The mixture is then put through a reduction process, being kept in the powdered form known as " Genelite powder," until the final steps. These consist of pressing the partially reduced powder in heavy steel molds under a high pressure as nearly as possible to the desired size and shape, and then giving it a final heat-treatment. Besides its use for bearings Genelite is also used for facing the rotating parts of valves used in systems handling caustic solutions. Among the properties claimed for this material are those of not sizing or sticking and of being somewhat self-lubricating. The material has the appearance of bronze and can be easily ground, but is not easily

machined. It was developed in the research laboratory of the Genera Electric Co.

GENERATING GEAR TEETH. See Gear Generating.

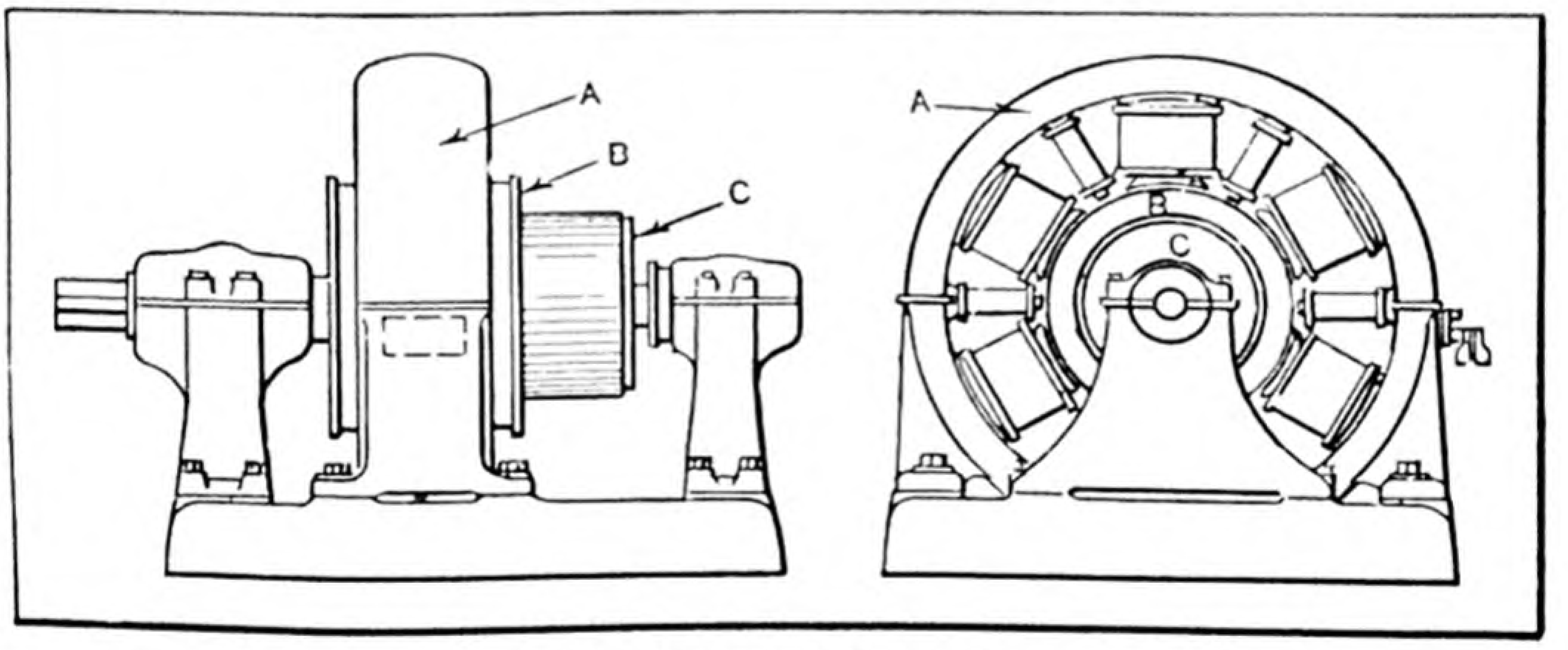
GENERATOR, ALTERNATING-CURRENT. An alternating-current generator, or alternator or synchronous generator, as it is also termed, is a machine that transforms mechanical power into electrical power. It has a magnetic field and an armature for delivering alternating currents in synchronism with the motion of the machine; that is, currents having a frequency strictly proportional to the speed of the machine. The instantaneous values of the electromotive forces (commonly written E.M.F.) and the currents are constantly changing from maximum positive to maximum negative, but the specified or effective value is equal to the square root of the average value of the square of the instantaneous values, which, for a true sine wave, is equal to the maximum value divided by $\sqrt{2}$. Almost all alternating-current generators are of the revolving-field type, because the transmission of a current under high voltage through collector rings and brushes, as required in the revolving-armature type, causes break-down troubles, as it is difficult to insulate the rings and brushes effectively. The stationary-armature winding, however, may be easily insulated, as it is not subjected to the mechanical stresses of the revolving-armature type and the crumbling from vibration imparted by a revolving member.

Alternating-current generators may be single-, two-, or three-phase machines, depending upon whether they generate a single alternating electromotive force, or two or more electromotive forces that differ in phase by a fixed amount; in the latter case they are also known as "polyphase generators." Three-phase generators are used almost exclusively on account of the saving that may be obtained. With the same line voltage and loss, the three-phase system will save about 25 per cent in the weight of the line conductors, as compared with either of the other systems — besides the reduced cost of line material and labor. Hence, when two-phase generators are required, it is usually for additions to an old system. The universal trade terms for alternating-current generators are: *ASB* for single-phase generators; *AQB* for two- or quarter-phase generators; and *ATB* for three-phase generators. In each case, *B* means revolving field.

GENERATOR, DIRECT- AND ALTERNATING-CURRENT. Both direct- and alternating-current electricity can be produced by a generator developed for use primarily with welding equipment. Because of the universal alternating or direct current feature, spot or tack, semi-arc and nickel-flash welding operations can be performed with alternating current, and if it is desired to perform other operations for which it is preferable

to use direct current, this kind of current can be obtained immediately. The full capacity of the equipment can be obtained with both currents. As the same armature winding serves for both currents, no extra space is required for the winding as compared with that necessary in a generator delivering only one of the currents. The only extra parts required are two collector rings for the alternating current. The main feature of the generator is that either the alternating- or direct-current leads can be short-circuited right at the collector rings or the commutator without injury; the generator voltage simply dies down to a value that holds the current constant, and there is no injury of the generators while in this condition. With the release of the short cirucit, the normal voltage is immediately obtained. The generator has a power take-off at both ends for driving equipment or machines.

GENERATOR, DIRECT-CURRENT. A direct-current generator is a machine that transforms mechanical power into electrical power, giving a current that is unidirectional or non-pulsating. It is constructed on the



Direct-current Generator

principle that a conductor moved across a magnetic field, in a direction at right angles to the lines of force or magnetic flux, will induce an electromotive force in that conductor. Direct-current generators are used for light, power, and railway service; for all purposes there is a close similarity in the electrical and mechanical design, the main difference being in the use of larger commutators for the first two, due to the lower voltage and greater amount of current to be handled.

The direct-current generator consists essentially of two distinct elements, a stationary field A, and a rotating armature B (see illustration). The field is composed of electromagnets of alternate polarity arranged in a circle, as shown, while the armature consists of a system of conductors arranged on an iron drum and operating in the magnetic field set up by

the electromagnets. As the conductors are acted upon alternately by north and south poles, the current generated in the conductors flows first in one direction and then in the opposite direction. To secure a constant flow of current in one direction, therefore, a device C, known as a *commutator*, is used to rectify the alternating, or pulsating, currents as they are generated in the armature conductors. This device, which constitutes a third essential element in a direct-current generator, consists of a number of copper segments or bars insulated from one another and connected to appropriate points of the armature winding. The potential, or voltage, of the bars will have a constantly varying value, which corresponds to the fluctuating potential induced in the conductors to which they are connected, as these conductors pass the pole pieces. The points of maximum potential on the commutator will, therefore, be equal to the number of field poles, as a conductor generates its maximum voltage while passing through the densest part of the pole flux; and although these maximum points are shifting rapidly from bar to bar around the commutator, their position relative to the stationary poles is fixed. This fact permits the collection of a constant-voltage direct current by means of contact brushes arranged to bear upon the commutator at equally-spaced points around its circumference.

Direct-current generators may be classified according to the manner in which they are "excited," that is, the manner in which the electromagnets are energized; they may be "separately excited," or "self-excited." When the generators are separately excited, the current for the field winding is taken from an outside source; when they are self-excited, it is drawn from the armature of the machine itself. Self-excitation is the form most commonly used on account of its simplicity, although the field current is then dependent upon the brush potential. When it is desirable to maintain a field strength independent of the brush potential, separate excitation should be used. Self-excited, direct-current generators may also be classified according to the manner in which the field windings are arranged; such as series-wound, shunt-wound, and compound-wound. See Series-wound Generator; Shunt-wound Generator; and Compound-wound Generator.

GENERATOR, DOUBLE-CURRENT. A double-current generator is a machine driven by mechanical power and producing direct current as well as alternating current from the same armature, which is connected to commutator and collector rings in the same way as in a synchronous converter. This type of machine is occasionally used for testing purposes.

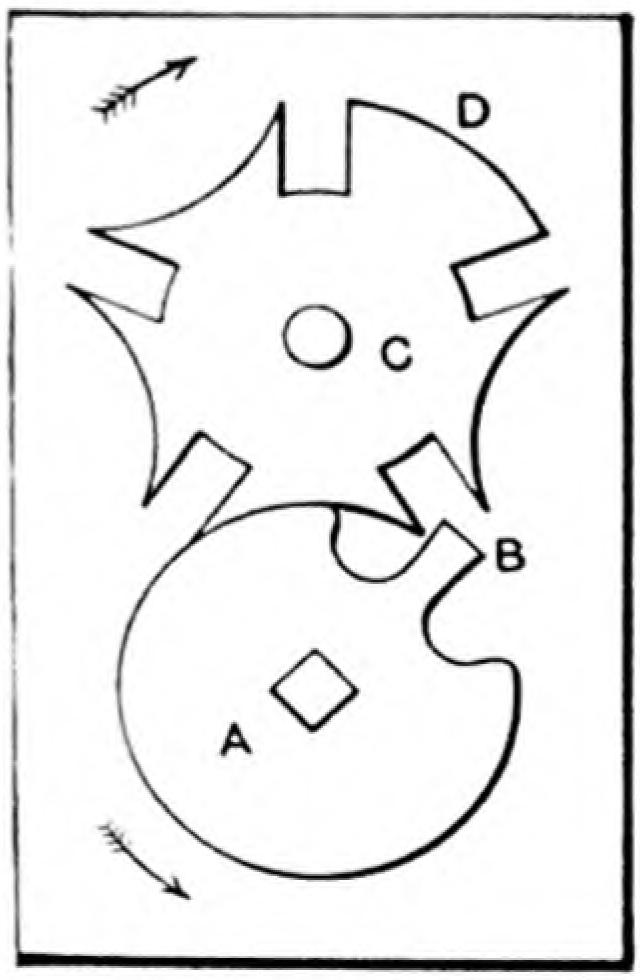
GENERATOR, INDUCTOR TYPE. The inductor generator is a synchronous type in which both the field and armature windings are stationary and only the pole pieces revolve. Due to the varying reluctance of the

magnetic circuit, caused by the revolving poles, the flux linked with the armature coils will vary periodically, and induce an alternating electromotive force in the armature winding. This type was extensively used before the introduction of the revolving-field alternator, which has proved to be far superior to the inductor alternator.

GENERATOR RATING. The capacity of a direct-current generator is expressed in kilowatts (usually written KW.) available at its terminals. The rated output is limited either by heating or sparking at the commutator or by both, so that the principle upon which the rating is based, so far as it relates to the thermal characteristics, is that the rated load applied continuously or for a stated period will produce a temperature rise that, superimposed upon a standard ambient temperature, will not exceed a maximum safe operating temperature of the insulation. Different manufacturers have made temperature guarantees that vary slightly. It has been recommended that direct-current generators should be given a maximum continuous rating at a temperature rise on all parts, except the commutator, not exceeding 50 degrees C.; the permissible rise of the commutator is somewhat greater. This rise is to be based on a room temperature of up to 40 degrees C.

GENERATOR WINDING. See Compound-wound Generator; Series-wound Generator; Shunt-wound Generator.

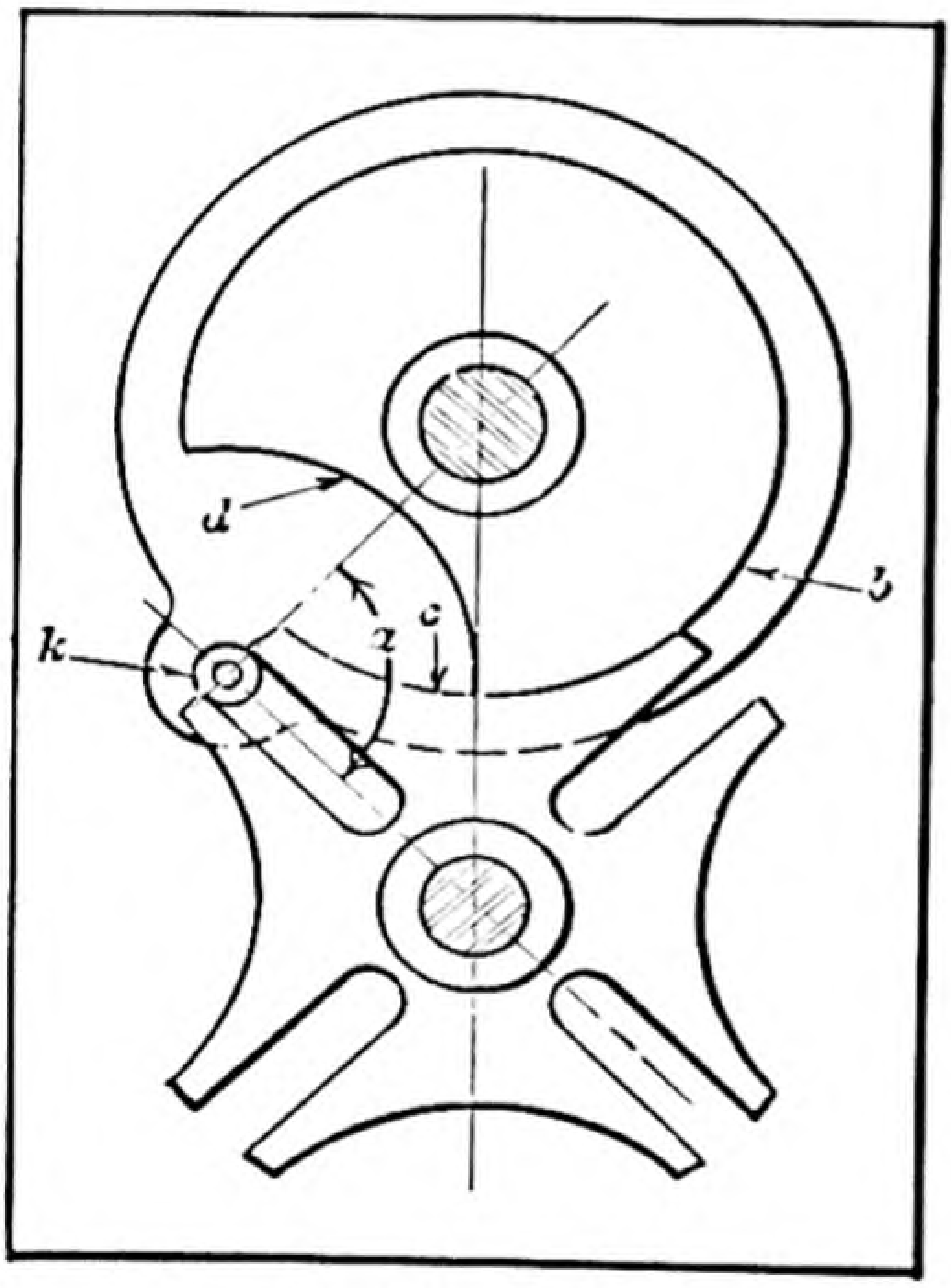
GENEVA STOP. The Geneva stop is a simple form of mechanism applied to watches, etc., to prevent winding the main spring too tightly. The principle of the mechanism is illustrated by the diagram. A disk *A* has one projecting tooth *B*, and is fixed upon the spindle of the barrel or casing containing the main spring. Another disk *C* provided with notches that are engaged by tooth *B* is rotated through part of a revolution each time tooth *B* makes one complete turn and engages one of the notches or tooth spaces. As that part of disk *C* between the notches is curved to the same radius as disk *A*, disk *C* is locked and prevented from rotating during the time that the tooth *B* is out of engagement. When disk *A* is turned, the intermittent motion of disk *C* continues until the convex portion *D* comes around into engagement with disk *A*, thus preventing any further rotation. With this arrangement, the number of revolutions for disk *A* can be positively regulated so that over-winding of the spring is avoided. When the winding action has ceased, the disks will return to their original positions



Geneva Stop

as the mechanism of the watch is driven by the spring and runs down. The principle of the Geneva stop has been applied to various classes of machinery in order to obtain the intermittent motion resulting from this form of mechanism.

GENEVA WHEEL. The general type of intermittent gearing shown in the illustration is commonly known as a " Geneva wheel," because of the similarity to the well-known Geneva stop. Geneva wheels are frequently used on machine tools for indexing or rotating some part of the machine through a fractional part of a revolution. The driven wheel shown in the illustration has four radial slots located 90 degrees apart, and the driver carries a roller *k* which engages one of these slots each time it makes a revolution, thus turning the driven wheel one-quarter revolution. The concentric surface *b* engages the concave surface *c* between each pair of slots before the driving roller is disengaged from the driven wheel, which prevents the latter from rotating while the roller is moving around to engage the next successive slot. The circular boss *b* on the driver is cut away at *d* to provide a clearance space for the projecting arms of the driven wheel. In designing gearing of the general type illustrated, it is advisable to so proportion the driving and driven members that the angle α will be approximately 90 degrees. The radial slots in the driven part will then be tangent to the circular path of the driving roller at the time the roller enters and leaves the slot. When the gearing is designed in this way, the driven wheel is started gradually from a state of rest and the motion is also gradually checked.



Geneva Wheel

GEOMETRICAL PROGRESSION. A geometrical progression is a series in which each term is derived by multiplying the preceding term by a constant multiplier called the *ratio*. When the ratio is greater than 1, the progression is increasing; when smaller than 1, it is decreasing. Thus, 2, 6, 18, 54, etc., is an increasing geometrical progression with a ratio of 3, while 24, 12, 6, etc., is a decreasing progression with a ratio of $\frac{1}{2}$.

GEOMETRIC LATHE. The machine known as a " geometric lathe " is a special machine designed for engraving intricate designs on fine dies

or plates. The elaborate scroll work found on paper money is an example of the engraving done by the geometric lathe. While this machine is known as a "lathe," it is, in reality, a highly specialized type of engraving machine. The geometric lathe was invented by Charles W. Dickinson, and was first used for engraving bank-note plates in 1862. This machine produces an almost endless variety of geometric figures by utilizing various combinations of gears, cams, and eccentrics. By varying the patterns for treasury notes, postage stamps, revenue stamps, etc., counterfeiting is made difficult. Moreover, the operation of one of these machines requires an expert mathematician. The lathe has a number of superimposed flat plates which are actuated by cams and gearing, and the die to be engraved is held by the top platen or chuck. The hardened steel tool which is sometimes pointed with a diamond is fastened in a stationary position, and the die is given the various movements necessary to produce each pattern.

GEORGIA CORUNDUM. This is a natural abrasive containing about 77 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. It is mined in Georgia; hence the name.

GERMAN SILVER. German silver, also known as "nickel silver," is an alloy of copper, nickel, and zinc, the best quality consisting of 50 per cent of copper, 25 per cent of nickel, and 25 per cent of zinc. This quality, however, is the most difficult to work, but takes a fine polish and is frequently used for tableware to imitate silver. When the proportion of copper is somewhat higher, the alloy is suitable for rolling and for drawing into wire. German silver is known under probably a greater number of names than any other alloy. In addition to the name "nickel-silver," it is also known as "Chinese white silver," or "packfong," "white copper," "silveroid," "Nevada silver," and "electrum." German silver can be hammered, rolled, stamped, and drawn. At the same time, it possesses the properties of being hard, tough, and not easily corroded, but, when exposed to the air, it tarnishes, becoming slightly yellow. At a heat above dull red, it becomes very brittle. German silver can be readily soldered. The usual composition of German silver solder is: Copper, 47 per cent; nickel, 11 per cent; and zinc, 42 per cent.

GESNER PROCESS. A method for producing a coating on iron or steel to protect it from the corrosive effects of the atmosphere, known as the Gesner process, consists in heating the steel parts in a retort at a temperature of about 1100 degrees F. for twenty minutes, and then allowing steam at low pressure to act upon the parts for about thirty-five minutes, after which a small quantity of naphtha or other hydrocarbon gas is let into the retort for about fifteen minutes. The coating produced is assumed

to be a compound of hydrogen, nitrogen, and carbon, and adheres firmly to the treated articles.

GHERKIN'S LATCH. This is a mechanism used for automatically returning a machine member to the starting point or central position after it has been thrown out of this position by the action of the machine.

GIBS. A gib (also known as an adjusting or take-up strip) may be defined as a wedge or adjusting shoe the object of which is to insure a proper sliding fit between two machine parts, and to make possible the taking up of the wear after the proper adjustment has been lost through continued service. Briefly, therefore, the function of the gib may be said to be to prevent slackness between the slide and its slide-way, and to compensate for wear. Gibs are used extensively on various classes of machine tools. Gibs may be divided into three main groups, according to the mode of "setting-up" or adjusting: These groups include (1) gibs forced laterally by screws acting at right angles to the axis of the slide; (2) angular gibs pulled or forced sideways so as to have a wedge action between the slide and the slide-way; (3) gibs tapered longitudinally and forced in that direction, thus having a wedge action.

GILBERT. Gilbert is the unit of magnetomotive force, and is the amount of magnetomotive force that can be produced by a coil of $10 \div 4\pi$ ampere-turns, or 0.7958 ampere-turn. The magnetomotive force of a coil equals 1.2566 times the ampere-turns. The symbol used to designate magnetomotive force is F.

GINSAW FILE. Ginsaw files are of knife shape and single-cut. This type has been supplanted, to a considerable extent, by the three-square ginsaw file, which is made either tapering or blunt of hand-saw slim steel, and is used for filing cotton ginsaws.

GIOLITTI PROCESS. This is a method for carburizing work to be casehardened by packing the work with wood charcoal in a cylinder, heating the work to a carburizing temperature, and then injecting a current of carbon dioxide into the cylinder. With the use of this process, a more rapid penetration of the carbon at the surface of the work can be obtained than with an ordinary solid carburizing mixture.

GIRDER. A beam of wood or iron, which is supported at each end upon walls or piers, and which supports a superstructure or load, such as a floor, a wall, or the roadway of a bridge, is known as a *girder*. When a girder is composed of upper and lower horizontal members united by vertical and diagonal bars, the girder is known as a *lattice* girder. When built up from steel plates and angles into compound shapes, forming I-beams or T-beams, the girder is commonly known as a *plate* girder. If built up

from plates and angle irons to form a rectangular cross-section, the girder is known as a *box* girder. All girders, however, in their mechanical sense are *beams*.

GLASS CUTTING. Sometimes it is necessary to cut plate glass so as to leave the edges smooth and straight. If this work is attempted with the aid of a diamond glass cutter and rule, the glass will break with a ragged edge. A method of overcoming this difficulty, which has been used in cutting plate glass as thick as ½ inch and with excellent results, is as follows: First obtain a good diamond glass cutter, and with this tool scratch the glass along the line on which it is to be cut, using any good straightedge to guide the diamond. In this connection it may be mentioned that the deeper the cut the more uniform the surfaces of the cut edge will be. After laying the glass on a cold surface with the cut side up, for which purpose the surface plate is very satisfactory, an iron or steel rod about ¼ inch in diameter is heated to a dull red. This rod is then laid along the line scratched by the diamond point and pressed lightly against the glass. When held in position for from one to four minutes — depending on the thickness of the glass — it will be found that the glass will crack along the line, leaving a uniform surface.

GLASS DRILLING. There are several methods of drilling holes in glass. For holes of medium and large size, use brass or copper tubing, having an outside diameter equal to the size of hole required. Revolve the tube at a peripheral speed of about 100 feet per minute, and use carborundum (80 to 100 grit) and light machine oil between the end of the pipe and the glass. Insert the abrasive under the drill with a thin piece of soft wood so as to avoid scratching the glass. The glass should be supported by a felt or rubber cushion, not much larger than the hole to be drilled. If practicable, it is well to drill about halfway through and then turn the glass over and drill down to meet the first cut. Any fin that may be left in the hole can be removed with a round second-cut file wet with turpentine. For comparatively small holes, a solid drill is often used. Use steel rod or an old three-cornered file, grinding the end to a long tapering triangular shaped point. Grip the drill in a chuck and rotate rapidly. Use a mixture of turpentine and camphor as a lubricant. Holes up to ½ inch in diameter can be drilled in glass with a flat drill which has been hardened in sulphurous acid, a mixture of turpentine and camphor being used as a lubricant. Ordinary twist drills are also used for drilling glass, the turpentine and camphor mixture being used as a lubricant. The glass is drilled about halfway through and then turned over so that the remaining depth may be drilled from the opposite side.

GLASS GRADUATING. See Graduating on Glass.

GLASS, NON-SHATTERING. A triplex non-shattering glass that will resist shock, is made by placing a thin sheet of zylonite (celluloid) between two sheets of glass and causing them to adhere by a special process under heat and pressure. The glass is transparent, sound-proof, air-tight, and water-tight even when badly cracked. A number of panels of the glass varying from $\frac{1}{2}$ to 1 inch in thickness were subjected, one at a time, to the fire of a 45-caliber automatic pistol at ranges varying from 1 to 15 feet. The bullet penetrated only about $\frac{1}{32}$ inch and was torn to shreds. Thinner panels, when subjected to this test, showed that some of the glass became detached from the reverse side, but in the case of thicker panels the reverse surface crumbled at the center and fell out in powdered form, but did not fly. This glass is particularly adaptable for safety goggles for workmen in steel mills and other industrial plants. It can be substituted in every case where common glass is ordinarily used.

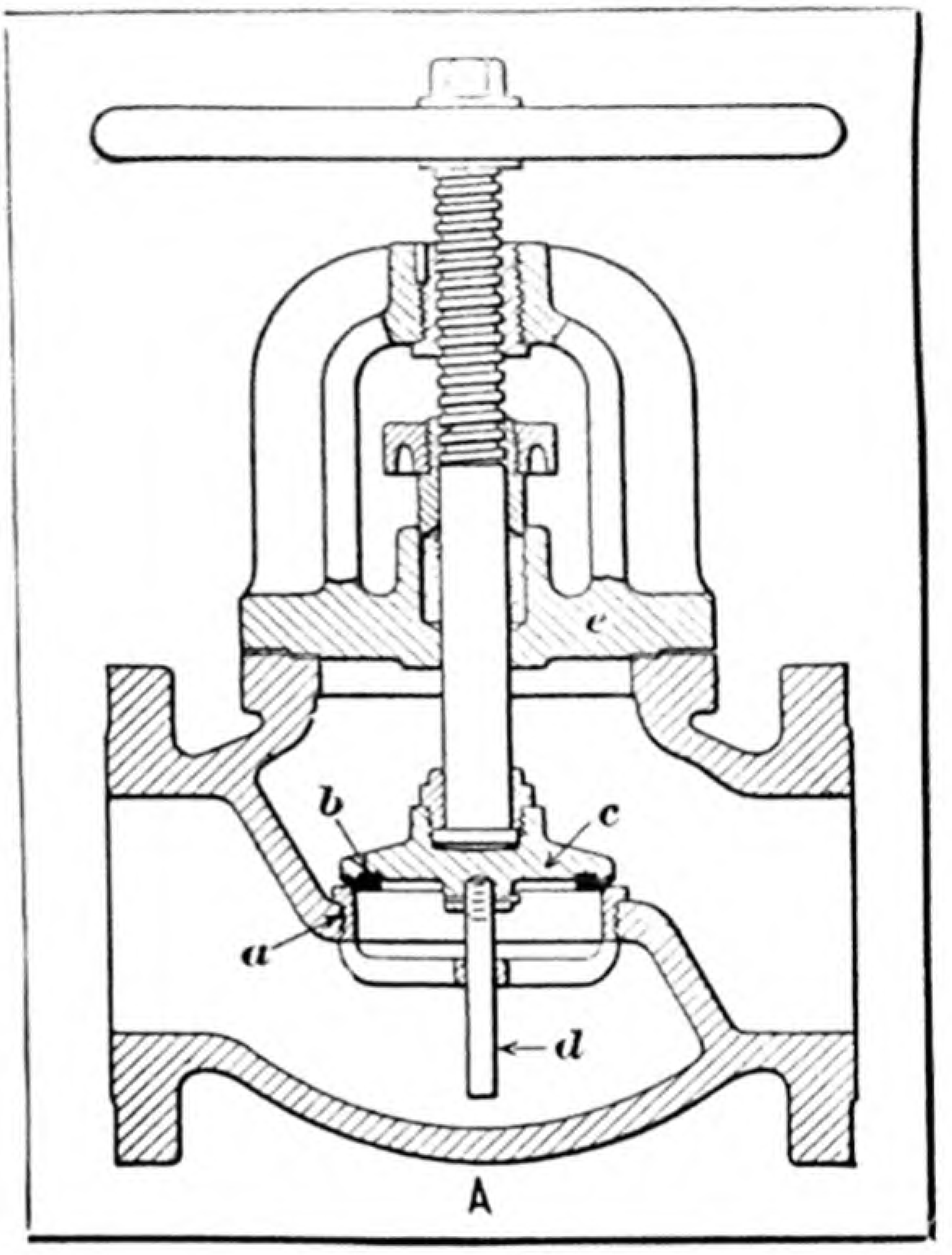
GLAZED GRINDING WHEEL. A wheel is "glazed" when the cutting particles have become dull or worn down even with the bond, which latter is so hard that the abrasive grains are not dislodged when too dull to cut effectively. Glazing may indicate either that the wheel is too hard for the work, or that the wheel speed is too high. The remedy, then, for glazing is to decrease the speed or use a softer wheel.

GLAZING. The roughing operation, preparatory to finishing knife blades and cutlery, is performed with solid grinding wheels and the polishing is known as fine or blue glazing, but these terms are never used when referring to the polishing of hardware parts.

GLEASON SYSTEM OF BEVEL GEARS. See Bevel Gears, Gleason System.

GLOBE VALVES. One of the heavier types of globe valves is shown by the sectional view. This type of valve has a metal seat formed by the screw bushing *a*, against which the ring *b*, which forms a portion of the disk *c*, is forced by the raising or lowering of the stem to which the handwheel is attached. In this particular valve, the bronze bushing is provided with a guide through which a pilot *d* on the end of the valve-stem passes in order to assist keeping the moving parts in their correct positions. The stem of the valve passes through the bonnet *e* and is made tight by packing it with suitable material. In smaller valves of the globe type, a metal seat is not always employed, a ring of fiber or vulcanized rubber composition being used instead. A fiber ring of this kind can be easily replaced, so that the valve can be kept tight without trouble. The smaller valves are also made with metal seats so constructed that they can be readily reground to make the seat perfectly tight. Valves which have this provision

are generally termed *re-grinding valves.* The screw on the valve-stem is generally of coarse pitch, and is sometimes a multiple screw, so as to permit opening the valve quickly. Valves of this kind are frequently made in angle form in order to take the place of elbows in the piping. There is a difference of opinion regarding which should be the pressure side of the valve. Many prefer to so connect the valves that the pressure is against the under side of the disk, as with this arrangement the stem of the valve can be readily packed when the valve is closed. When the pressure is on the top side of the disk, however, there is an advantage in that the thrust is against the valve-seat and not against the threads of the valve-stem.



Globe Valve

GLOBOID GEARING. See Hindley Worm-gearing.

GLOW DISCHARGE TUBE. A so-called "grid controlled glow discharge tube" is an extremely sensitive tube that glows and discharges sufficient energy to actuate a relay by the mere act of placing a human hand near its grid plate. The energy from one ounce of coal can operate it 17,000,000,000 times. It operates on approximately one-billionth of an ampere.

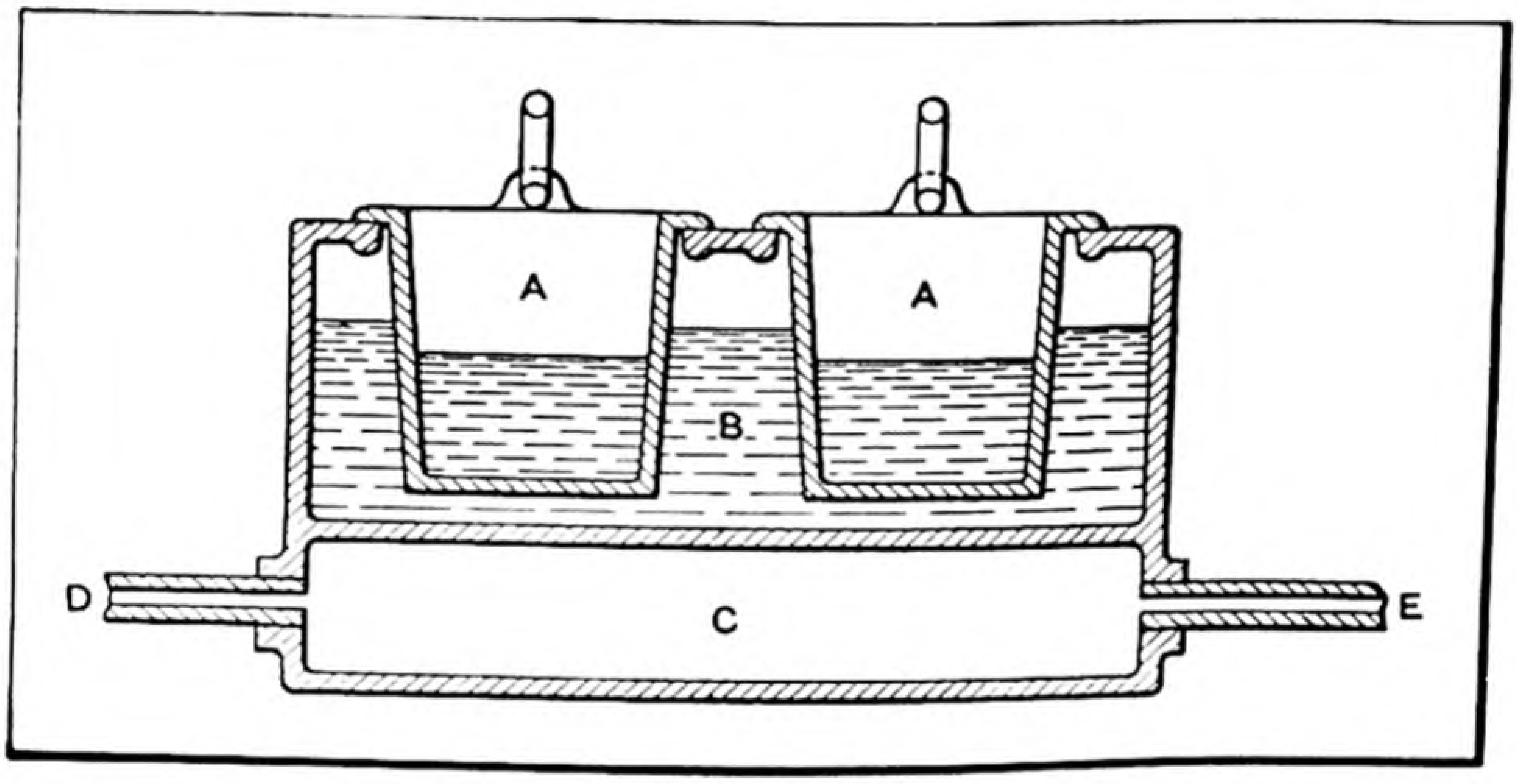
The device consists of three electrodes — a negative electrode and a positive electrode, the latter being surrounded by a grid which constitutes the third electrode. Differing from the ordinary vacuum tube, this glow tube has no heated filament, and therefore does not consume any energy when not operated. If a voltage is applied between the positive and negative electrodes, particles of electricity called "free electrons" attach themselves to the grid. When this grid is thoroughly insulated, these minute charges of electricity cannot escape, thus preventing the tube from passing any current. When a hand is placed near the plate, a means is provided for removing the small charges of electricity. The result is that the tube immediately passes a current large enough to operate commercial relays.

Some commercial applications are as follows: Fire protection; when used for this purpose, the smoke or flame would serve to operate the tube.

Burglar alarm; the grid of the tube can be attached to desk, window, drawer, or vault, and as soon as the tube is touched, it operates a relay. Gas furnace flame control; serving in this agency, the glow tube would insure that the pilot flame was kept burning. Other uses include automatic gaging of the depth of oil or water tanks.

GLUCINUM. Glucinum is an alternative name used for the chemical element *beryllium;* the symbol is Gl, or sometimes G. The name " beryllium " has been used for many years, but recently the original name "glucinum " has been adopted by chemists, and both names are used to some extent, at the present time. For the properties of the element, see Beryllium.

GLUE HEATERS. Glue is always heated or boiled in a double boiler to prevent overheating and burning. The glue is placed in a pot that fits



Steam Glue Heater

into a vessel containing water. The water in the outer vessel is heated either by an open flame, an electric current, or by steam. A sectional view of a simple steam glue heater is shown. The receptacles *A* are for holding the glue; *B* is the water container, and *C* is the steam jacket. The live steam enters at *D*, passes through the jacket and out at *E*. The flow of steam is controlled by a globe valve at the inlet.

GLUES FOR WOOD. The glues that are adapted for gluing wood, according to a report of the Forest Products Laboratory, U. S. Forest Service, Madison, Wis., may be conveniently divided into five classes as follows:

1. Animal glues, which are made from the hides, hoofs, horns, bones, and fleshings of animals, mostly cattle. These glues come in dry form, and must be mixed with water and melted.

2. Casein glues, which are made from casein, lime, and certain other

chemical ingredients. They are commonly sold in prepared form, requiring only the addition of water, but may be mixed by the addition of the separate materials to the water.

3. Vegetable glues, which are made from starch, usually cassava starch, and sold in powdered form. They may be mixed cold with water and alkali, but heat is commonly used in their preparation.

4. Blood-albumin glues, which are made from soluble blood albumin, a product recovered from the blood of animals. These glues must be mixed just before use, since they deteriorate rapidly on standing.

5. Liquid glues, which are commonly made from the heads, skins, bones, and swimming bladders of fish. Some liquid glues are made from animal glue and from other materials. They come in prepared form ready for immediate use.

Animal Glue. — Animal glue, frequently referred to as "hot glue," is familiar to all woodworkers. The principal desirable properties of animal glue are its great strength and reliability in the higher grades, its free-flowing consistency, and the fact that it does not stain wood. So far no glue has been found to be as suitable as animal glue for handspreading on irregular shaped joints. The price of animal glue is the chief factor that limits its use. The fact that it is not highly water-resistant is occasionally a drawback.

Casein Glue. — Casein glue has sufficient strength for either veneer or joint work. It is used cold, and when properly mixed it can be spread with a brush. The property most featured is its high water-resistance, which makes it suitable for gluing articles to be used under moist conditions. Not all casein glues are water-resistant, however; there are some on the market which are made to compete with vegetable glue, and for which no great water-resistance is claimed. Among the disadvantages of casein glues are their tendency to stain thin veneer and the relatively short working life of some kinds. It is claimed that this trouble has been overcome to a certain extent in some glues. They are somewhat harder on tools than animal and vegetable glues.

Vegetable Glue. — Vegetable glues have found wide use because they are cheap, can be used cold, and remain in good working condition free from decomposition for many days. They are extremely viscous, and it is not practicable to spread them by hand. Their lack of water-resistance and the fact that they usually cause staining in thin fancy veneer are factors limiting their use. They set relatively slowly, and for this reason are not so well adapted for joint work.

Blood-albumin Glue. — Blood-albumin glue has shown notably high resistance to moisture, especially in the boiling test. This makes it particularly suitable for gluing plywood which is later to be softened in hot water and molded. The production of molded plywood articles has been

very limited, but it offers a good field for future development. In the past the chief drawback to the use of blood glues has been the necessity for hot-pressing, but tests have shown that a highly water-resistant blood glue may be developed which can be cold-pressed successfully.

Liquid Glue. — Liquid glues are, in general, similar in properties to animal glue. Some brands are quite equal in strength to good joint glues, but other brands are very weak and unreliable. Their great advantage is that they come in prepared form, ready for immediate use. This makes them particularly suitable for patch work and small gluing jobs. The factors that limit their use are their high price, their lack of water-resistance, and the difficulty in distinguishing between good and poor brands.

Veneer and Joint Glues. — Generally speaking, present vegetable and blood-albumin glues are veneer glues, while animal and casein glues are used both as veneer and as joint glues. As between animal and casein glue for joint work, if freedom from staining is important, animal glue is preferable; if water-resistance is of importance, then a casein glue should be selected. Because of the necessity of heat in the preparation and use of animal glue, the casein cold glue will probably be favored if both glues are otherwise equally well adapted.

GLUES USED IN POLISHING. There are three kinds of glue, namely, bone, hide stock, and fish glue. Hide stock glue is most generally used in the polishing industry. It is made from the skins of cattle, rabbits, and other animals. Glues are often blended; for example, a sheep stock and goat stock glue make an exceptionally strong holding medium, and, when mixed with ox fleshings, form a glue which has more strength than a glue made entirely from rabbit or some other similar stock. The cheaper grades of glue are usually mixtures of bone and hide glues.

GLUING PRACTICE. The following information on gluing practice is based upon a report of the Forest Products Laboratory, United States Forest Service, Madison, Wis.

Weakness in glued joints may be caused (1) by allowing the glue to become too cold before applying pressure; (2) by using glue that is too thin and is squeezed out of the joint; or (3) by allowing the glue to dry too much before applying pressure. These three mistakes are the most common ones in gluing practice, and they are known as the "chilled joint," the "starved joint," and the "dried joint," respectively.

Strong joints may be obtained by changing either pressure, assembly time, or temperature, these being the three most important factors in the gluing operation when animal glue is used. Thus a good joint can be made from chilled glue by increasing the pressure, or the glue may be kept from becoming chilled and a good joint obtained if either the assembly

time is decreased or the room temperature increased. If the glue is thin, starved joints may be avoided by decreasing the pressure, although such practice is not always recommended. Better average results are obtained if the consistency of a thin glue is increased either by increasing the assembly time or by decreasing the room temperature.

No amount of pressure will produce a good joint from dried glue, but by decreasing either the assembly time or the temperature to which the wood is subjected, a good joint can be made before the glue has dried out. Assembly time, room temperature, and wood temperature are chief among the factors affecting the consistency of an animal glue at the moment pressure is applied. Pressure then must be adjusted to suit the consistency of the glue, the thicker mixture requiring the greater pressure.

GLYCERINE ANTI-FREEZING MIXTURES. See Anti-freezing mixtures.

GLYCERINE IN HYDRAULIC MACHINERY. Glycerine has been used extensively in hydraulic presses and similar machinery because it acts to a certain extent as a lubricant, preserves the flexibility of cup leathers, has a high viscosity which makes it less likely to leak through fine pores in castings and defects in joints, and, finally, freezes at a very low temperature. It is also found that in many instances glycerine acts as a protection against corrosion of metallic surfaces. There are, however, other instances where apparently it either induces or accelerates corrosion. From an extensive investigation it would appear that whenever two metals of different electrical potential are employed in hydraulic apparatus with glycerine as the working fluid, the metal that constitutes the negative pole of the electric couple is always the one attacked. The conclusion is that in hydraulic or hydro-pneumatic apparatus employing glycerine as a working fluid, the parts should be so selected that contact of two different metals in the presence of the glycerine is always avoided.

GOLD AMALGAM. Alloys formed by mercury and other metals are known as *amalgams*. Gold amalgam is an alloy of gold and mercury. It is used in gilding.

GOLD, MANNHEIM. See Mannheim Gold.

GOLD-PLATING. Gold is universally plated from a solution of potassium gold cyanide, $KAuC_2N_2$, held in solution by potassium cyanide. The appearance of the deposited gold depends upon the temperature of the bath. A hot bath gives deposits of greater density and uniformity, and richer tones. Any other metal than copper must be copper-plated before gilding. The following bath is suitable for cold gilding: 54 grains of gold in the form of fulminating gold, from 0.35 to 0.5 ounce of 98-per-cent potas-

sium cyanide, and 1 quart of water. Fulminating gold is prepared by adding ammonia to a solution of gold chloride. The fulminating gold is precipitated, filtered, and washed, and then dissolved in potassium cyanide, while still moist; if dried, it is highly explosive. Too much potassium cyanide causes the gilding to be pale. The following bath is suitable for hot gilding: 15.4 grains of gold in the form of fulminating gold; 77 grains of 98-per-cent potassium cyanide; and 1 quart of water. The temperature is from 158 to 176 degrees F. The current density used in gold-plating is from 0.93 to 1.4 ampere per square foot, at from 1 to 3 volts; the anodes are of fine gold. When very large objects are to be gilded, anodes of corresponding dimensions are required in order to insure a uniform current density. As it would be too expensive to use large gold plates, carbon may be substituted.

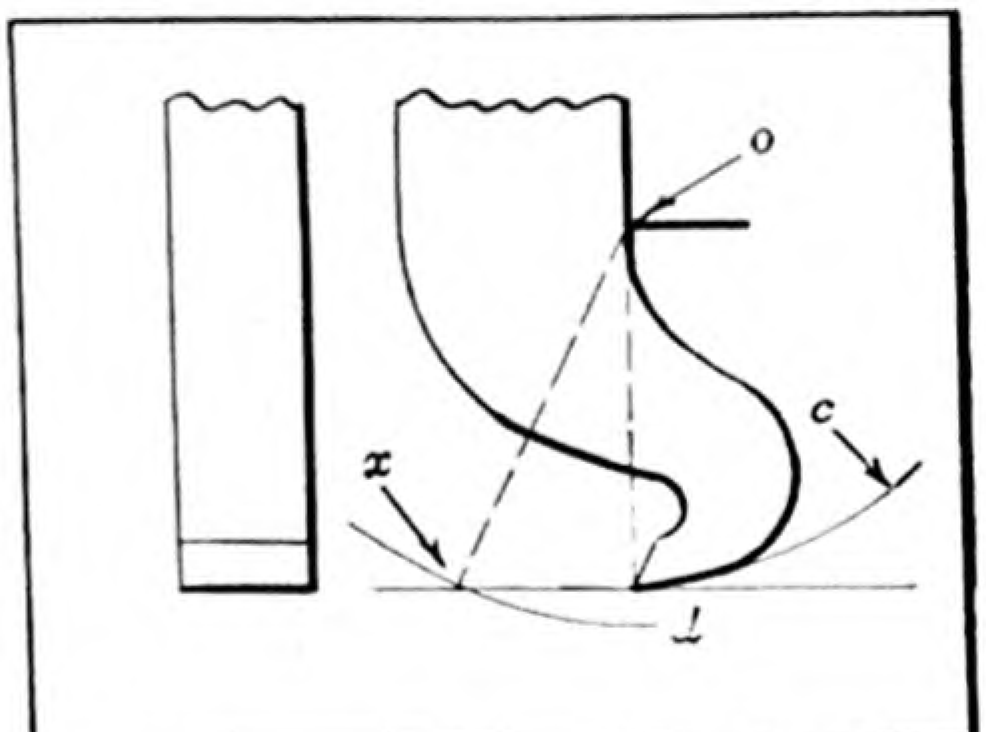
When gold-plating the insides of silver-plated utensils, the gold solution is poured into the vessel, and a gold anode suspended in the center from the positive pole of the generator; the negative is attached to the article itself. Pewter vessels are first copper-plated before undergoing the gilding or silvering process. During the operation of plating, it improves the solidity of the deposition to scratch-brush frequently, which also prevents the work turning to a dead brown-black. Red gilding is produced by the addition to the bath of copper cyanide in small amounts until the proper color is obtained. Green gilding is produced by the addition of silver cyanide. See also Electroplating.

GOLD PROPERTIES. Gold is the most malleable of all metals and is also extremely ductile. It may be beaten into leaves thin enough to transmit a greenish light, and one grain of gold has been drawn into wire 500 feet in length. One of the most remarkable properties of gold is that it is permanent in both moist and dry air at all temperatures, and that it is insoluble in all acids except in aqua regia (a mixture of hydrochloric and nitric acids) which will dissolve it. Chlorine and solutions that generate chlorine will dissolve gold. Pure gold is rarely used in the arts or industries, because of its softness, it being nearly as soft as lead and much softer than pure silver; it is, therefore, generally alloyed with either copper or silver. Gold coins and gold ornaments are always made of alloys of gold and copper, or gold, copper, and silver. The coins of the United States are composed of 9 parts of gold and 1 part of copper. The specific gravity of gold, when cast, varies from 18.3 to 19.35, but the specific gravity of pure gold obtained by precipitation may be anywhere from 19.55 to 20.7. Generally, the specific gravity of commercial gold is given as 19.3. The melting point of gold is 1063 degrees C. (1945 degrees F.). As a conductor of electricity, gold ranks next to silver and copper. Its electrical conductivity is equal to 76.7 (silver = 100).

GONDA CELL. This is a primary cell or battery practically the same as the Leclanché cell, except that the porous cup in the latter cell in which the carbon cathode is placed is not used. In the Gonda cell, the manganese dioxide is mixed with granular carbon and some adhesive substance, and then pressed into cakes which are placed on each side of the carbon electrode.

GONIOMETER. The goniometer is an instrument used for measuring the angles of crystals. There are two kinds of goniometers, the *contact* goniometer and the *reflecting* goniometer. The first type is somewhat similar to the simplest type of draftsman's protractor, except that it is provided with an arm or rule pivoted at the center of the graduated semi-circle. The reflecting goniometer is an instrument of great precision, and is always used for accurate measurements of angles, when small crystals with bright faces are available. Several forms of this instrument have been devised, all being based upon the reflection of the light from the crystal faces.

GOOSE-NECK TOOL. The peculiarly-shaped tool shown by the front and side views of the accompanying diagram, is especially adapted to finishing cast-iron surfaces. This type is known as the "goose-neck," because of its shape, and it is intended to eliminate chattering and the tendency which a regular finishing tool has of gouging into the work. By referring to the side view which represent this type of tool applied to a planer, it will be seen that the cutting edge is on a line with the back of the tool shank, so that any backward spring of the tool while taking a cut would cause the cutting edge to move along an arc *c* or away from the work. When the cutting edge is in advance at some point *x*, as with a regular tool, it will move along an arc *d*, if the strain of the cut causes any springing action, and the cutting edge will gouge in below the finished surface. Ordinarily, the tool and the parts of the planer which support it are rigid enough to prevent such a movement, so that the goose-neck tool is not generally used.



Goose-neck Planer Tool

GORDON CELL. This is a primary cell or battery, largely used for signal work, which has a zinc anode and a copper or iron cathode, with an electrolyte made by dissolving $1\frac{1}{2}$ pounds of sodium hydroxide in 6 pints of pure water. A layer of paraffin oil preserves the electrolyte from evaporation. The cell has an electromotive force of about 0.7 volt and is used for open or closed circuits and large currents.

GORDON'S FORMULAS. These formulas were developed for the calculation of the strength of columns. They are also known as Rankine's formulas, which see.

GOVERNORS, ENGINE. The power developed by an engine may be changed either by varying the initial pressure or the point of cut-off. Governors which maintain a constant speed under variable loads by changing the initial pressure are called *throttling governors.* This form is uneconomical in the use of steam and is confined to the cheaper and less efficient types of engines, or where the cost of fuel is not of great importance. For high-speed engines employing a positive valve-gear, the shaft governor is commonly used. This operates by shifting the position of the eccentric upon the main shaft in such a manner as to produce the desired changes in the point of cut-off. Governors of this type act in two ways: Either by rotating the eccentric upon the shaft so as to change the angle of advance, or by swinging it in such a manner as to increase or diminish the throw, and thus change the travel of the valve. The first method not only changes the cut-off, but all other events of the stroke, if the governor is arranged to act upon the main valve, and, for this reason, it is confined chiefly to valves of the Meyer type having a riding cut-off. The swinging eccentric can be so pivoted that it will increase or decrease the travel of the valve, thereby changing the cut-off, while the lead may be increased or decreased at will, according to the design.

GOVERNORS, INERTIA AND CENTRIFUGAL. When the regulation of steam engine speed is automatically controlled, many of the governors used depend for their action upon the effect of centrifugal force on a rotating element. In the case of a "*fly-ball*" *governor* weights or balls attached to pivoted levers are revolved by the engine and if the speed increases above normal, the balls or weighted levers move outward from the axis of rotation, owing to the increase in centrifugal force. This change in the position of the revolving balls may be transmitted through suitable connecting levers and rods to a valve which partly closes, thus reducing the steam supply. When a governor of this type is applied to a Corliss engine, the release of the steam valves and the point of cut-off is controlled directly by the governor. Most governors of the fly-ball type are equipped with one or more springs which tend to resist the outward movement of the revolving balls.

The *inertia or centrifugal-inertia governor* is attached to the fly-wheel and regulates the speed by varying the position of the eccentric or crankpin that operates the valve. Generally, this governor has an inertia bar with enlarged ends to increase the weight at the ends. The bar is pivoted at some central point. Speed variations cause a slight movement of the

inertia bar about its bearing in one direction or another, and the bar is linked so as to change the position of the eccentric, which changes the point of cut-off. If the speed increases, the inertia bar lags behind momentarily and the steam is cut off earlier during the stroke because the eccentric swings inward and shortens the travel of the valve. If a sudden increase of load should cause the engine to run slower, the bar, as a result of its inertia, would tend to continue running at the faster speed, which would swing the bar forward about its bearing in the direction of rotation, thus increasing the valve travel and admitting more steam to the cylinder by delaying the point of cut-off.

GOVERNORS, WATER-WHEEL. See Water-wheel Governors.

GRADE OF GRINDING WHEEL. See Grinding Wheel Grade and Grain.

GRADUATING. The dividing of circular and straight scales into a given number of equal spaces or divisions is known as graduating. The type of machine or tool used for graduating and the method of producing the graduation marks or lines varies with different classes of work, depending upon the degree of accuracy necessary and the form of the parts to be graduated. The work of graduating may be divided into two branches, which include, first, the method of spacing, and second, the means for making suitable marks or lines upon the parts to be graduated.

The machines used in laboratories and by tool and instrument manufacturers, for graduating various kinds of straight scales, may be classified as the *precision screw* type and the *pantograph* type. The former is equipped with a very accurate lead-screw, which, by means of a suitable indexing or spacing mechanism, is rotated an amount depending upon the spacing required, and as this screw actuates the work-holding table, a tool that is given a cross-movement makes graduation lines either in a "resist" or directly upon the work. The pantograph machines have a pantograph mechanism which serves to reproduce, on a smaller scale, the graduation lines or figures which have been previously cut in a pattern or master scale.

The marks or lines which represent divisions or spaces on graduated scales, etc., may be formed by the etching process, by the direct-cutting action of a tool, or, for some grades of work, by the stamping or impression process. With the etching process, the part to be graduated is first covered with some acid-resisting material or "resist," as it is called, and then the lines or figures are cut into this resist by a mechanically-guided graduating tool, thus exposing the metal wherever these lines or figures are made. An etching acid is then applied, and, wherever the metal is exposed, the acid eats into the surface and forms the division lines. When very fine graduation lines are needed the general practice is to employ the direct-

cutting method, since the marks obtained by a very sharp-pointed tool are finer and more accurate than is possible to obtain by the etching process. See Etching " Resists " and Etching Fluids.

GRADUATING ON GLASS. When graduation lines are etched on glass, a resist of paraffin or beeswax may be used. The lines and any other additional figures or designs required are then drawn into the resist the same as when operating on metal. Concentrated hydrofluoric acid is used for etching glass, and a little pigment is sometimes rubbed into the etched lines to make them more visible.

" GRAIN " OF GRINDING WHEEL See Grinding Wheel Grade and Grain.

GRAM-CALORIE. Gram-calorie is a thermal unit based on the metric system, designating the amount of heat required for raising the temperature of one grain of pure water one degree C. One gram-calorie = 0.003968 British thermal units; 1000 gram-calories = 1 kilogram-calorie.

GRANITE. Granite is one of the rocks or stones consisting principally of quartz and felspar, which is valuable as a building material, as a material for foundations, etc. The general properties of granite may be specified as follows: The weight of granite per cubic foot is 170 pounds; the specific gravity averages about 2.72; the compressive strength per square inch is about 15,000 pounds; the shearing strength per square inch is about 2000 pounds; the tensile strength per square inch is about 1500 pounds; the modulus of elasticity is about 7,000,000; and the coefficient of linear expansion due to heat, for each degree F., is 0.000004.

GRAPHALLOY. Graphalloy is a trade name for a metalized graphite made by forcing molten metal into graphite of a porous nature by the appli ation of air pressures up to 5000 pounds per square inch. Graphalloy is adapted for bearing bushings where the application of oil is either objectionable, difficult, or likely to be neglected, and also for brushes and contacts for electrical machinery.

GRAPHIC FORMULA. In chemistry, a graphic formula is one which shows the valence of the atoms and the manner in which they are united in a compound.

GRAPHITE. Graphite is a form of mineral which consists of the chemical element carbon. Graphite is very dark in color with a bright metallic luster, and is one of the softest of the minerals. Its specific gravity is about 2.2. Graphite occurs in nature mainly in crystalline rocks, and is also produced artificially on a large scale in the electric furnace. In the industries, graphite is used as a lubricant, as a material for crucibles, for foundry

facings, and as a material for electrodes. It is also widely used in the manufacture of pencils, polishes, and paint. A special variety of graphite used for lubrication purposes is known as "deflocculated graphite." Deflocculated graphite, when suspended in water, is known by the trade name "aquadag." When suspended in oil, the trade name "oildag" is used. Graphite has valuable lubricating properties. See Deflocculated Graphite.

GRAPHITE CRUCIBLE. This is a pot or container made from a mixture of Ceylon graphite, clay, and pure sand, used for the melting of metals. Graphite crucibles are more generally used than clay crucibles, because they can be recharged cold, will stand rough handling, and have a longer life.

GRAPHITIC CARBON. This is carbon in the form of graphite. In cast iron it is merely mixed with the iron and is not in chemical combination with it. For the effect of graphitic carbon in cast iron, see Cast Iron.

GRAPHITIZING. Graphitizing, according to the S.A.E. definition, is a method of annealing cast iron whereby some or all of the combined carbon is transformed into free or uncombined carbon.

GRATE AREA. The grate area is the area of the grate of a furnace, usually expressed in square feet. A simple rule for calculating the grate area of a boiler when the probable rates of combustion and evaporation are known is as follows: Multiply the horsepower of the boiler by 34.5 and divide the result by the product of the rate of combustion times the rate of evaporation; the quotient is the grate area in square feet.

GRAVITY. The attractive force that exists between the earth and all bodies at or near its surface is called "gravity." Weight is due to gravity. A body has weight because it is pulled downward by the force of gravity, and the amount that it weighs is a measure of this pull. A piece of iron, for example, weighs one pound when it is of such a size and density that it is drawn to the earth by a force equal to that which attracts a standard pound weight. The weight of a body (that is, the force by which it is attracted to the earth) varies slightly with the locality. Thus weight varies with altitude. A body weighs the most at the surface of the earth, as the attraction is there the strongest. Below the surface its weight decreases in the same ratio that its distance from the center of the earth decreases. Above the surface, the weight decreases in the same ratio that the square of the distance from the center increases. Weight also varies with the latitude, or distance north and south of the equator. In passing from the equator to either pole, the attraction of gravity increases by $\frac{1}{588}$ of its original amount. This is due to the fact that the earth is not a perfect sphere, the polar diameter being 26 miles shorter than the diameter at

the equator. At the poles, however, a body would actually weigh more than this, or about $\frac{1}{193}$ more than at the equator. The difference, $\frac{1}{289}$, is due to the rotation of the earth on its axis, the effect of which is to produce a force directly opposite to that of gravity (centrifugal force), which is greatest at the equator and diminishes in moving from it, until at the poles it becomes zero.

Falling Bodies. — Under the influence of gravity alone, all bodies fall to the earth with the same velocity and with the same acceleration. The fact that heavy bodies actually fall more rapidly than those of less weight or density, as would be observed in the dropping of a stone and a leaf, is due solely to the greater retarding effect of the air upon the latter. Weight does not affect the time of fall. Weight is the measure of the attractive force of gravity, and if one body weighs twice as much as another, the attraction of gravity upon it is two times as great as upon the lighter body; but as this force must accelerate twice as great a mass in the former body as in the latter, the velocity of each must be alike. An apparatus used to prove this consists of a long glass tube with closed ends, so arranged that the air can be exhausted. When this has been done, it is found that objects of varying sizes and weights will fall from one end of the tube to the other with equal rapidity. The value of the acceleration due to gravity is commonly denoted by the letter g. The acceleration increases with the latitude and decreases with the elevation above the level of the sea. Its value at the level of the sea in the latitude of New York is 32.16 feet per second. (In the metric system g equals 9.81 meters per second at 45 degrees latitude and sea level.) As the velocity increases (is accelerated) 32.16 feet (or g) every second, the velocity after T seconds will be:

$$V = gT,$$

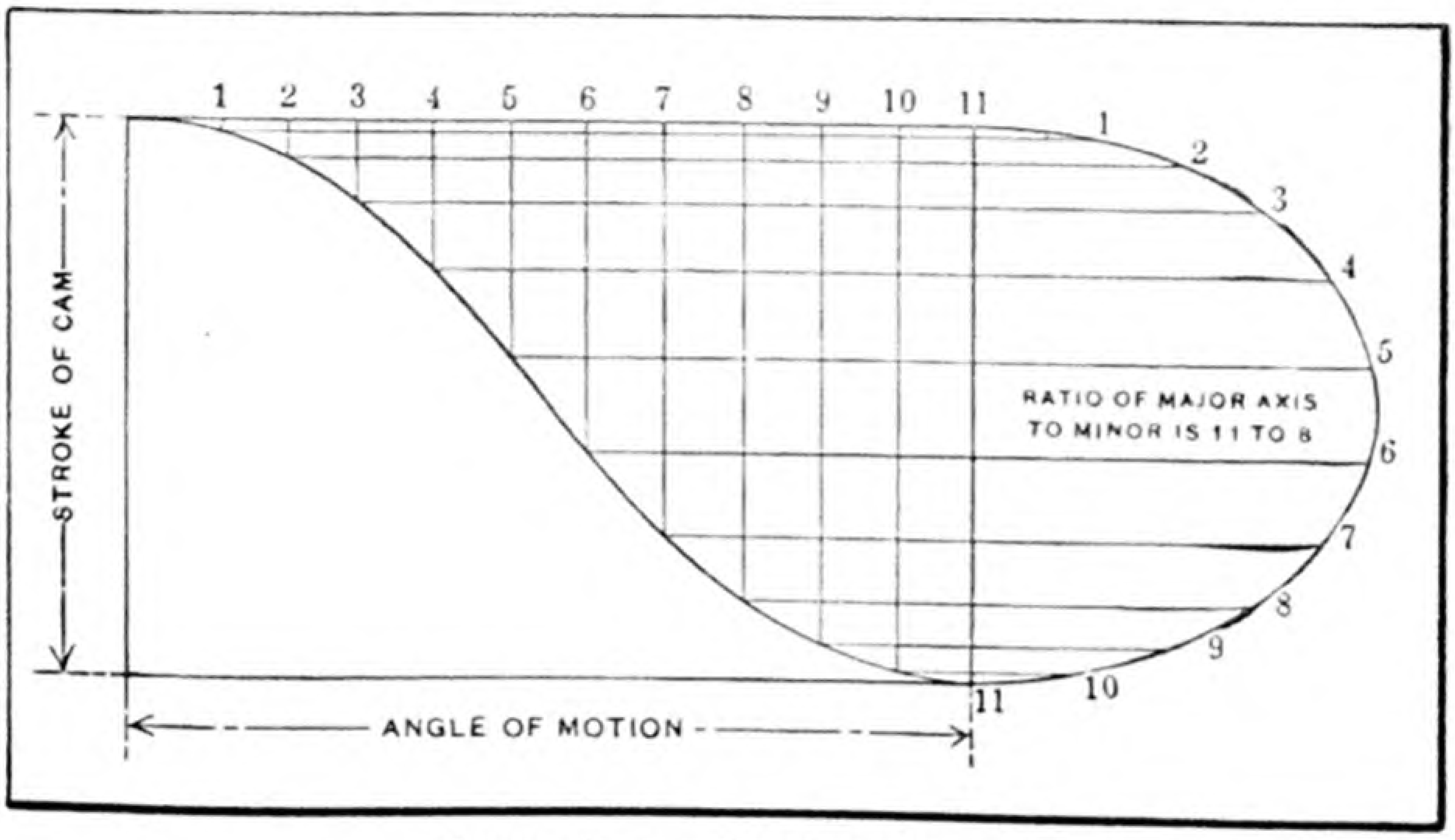
where V = velocity in feet per second. The space in feet passed through by the falling body in T seconds equals the average velocity (which is $\frac{1}{2}V$) multiplied by the time:

$$S = \frac{1}{2}\,VT,$$

where S = space in feet which the falling body passes through in T seconds. These two formulas are the basis of all formulas relating to falling bodies.

GRAVITY CURVE. An easy working cam curve is the one known as the "gravity curve." This curve has a constant acceleration or retardation bearing the same ratio to the speed as the acceleration or retardation produced by gravity; hence its name. A very close and satisfactory approximation for the gravity curve, and one that entails less work than the theoretical, is shown by the diagram. The method of drawing is similar to the

one used for harmonic motion, excepting that an ellipse takes the place of the semi-circle. It can be seen very readily that the ratio of the major and minor axes will determine the character of the cam curve. To obtain a curve that will approximate the gravity curve, the line representing the stroke of the cam should be used as the minor axis and the ratio of major axis to minor axis should be $1\frac{3}{8}$ to 1 or 11 to 8. By dividing the semi-



Approximate Gravity Curve

ellipse and line of angle of motion into the same number of equal parts, and projecting, points on the curve are obtained.

GRAVITY IDLER. The gravity type of idler used in conjunction with many belt drives, consists of a weighted idler pulley, so pivoted from a long arm that the idler runs near the small pulley against the loose side of the belt, in such a way as to increase the arc of contact of the belt on this pulley. These idlers are of especial value on difficult drives where there is a large difference in the diameter of the driver and driven pulleys. See Lenix Belt Drive.

GRAY CAST IRON. See Cast Iron.

GREEN BRASS. When brass contains from 20 to 25 per cent of zinc, it has a greenish-yellow color. Because of this color it is known as "green brass."

GREEN SAND CORE. A part of a foundry mold inserted in the mold cavity so as to form either a hole or a recess in the casting; made from ordinary green molding sand and not dried or baked. This is the cheapest kind of core that can be used for molding, but can only be used for plain cylindrical shapes or for patterns having such recesses that the core can be shaped in the molding sand in connection with the regular molding work.

GRENET CELL. This is a primary cell or battery which is practically identical with the Bichromate Cell, which see

GRIDIRON VALVE. This is a multiple-port type of engine slide valve designed to give a maximum opening with minimum travel. Both the valve and its seat contain a number of narrow openings or ports, so that a short movement of the valve will open or close a comparatively large opening. For example, if the steam valve has twelve openings, each $\frac{1}{4}$ inch in width, a movement of $\frac{1}{4}$ inch of the valve will open a space $12 \times \frac{1}{4} = 3$ inches in length.

GRINDERS, FLOOR-STAND TYPE. This type of machine is used for "hand grinding" and the grinder head is supported by a pedestal or floor stand. Machines of this type generally mount two wheels — one on each end of the spindle. Floor stands generally mount grinding wheels from 12 to 24 inches in diameter and from 2 to 4 inches thick. The spindle may be driven by a belt or the stand may be a self-contained machine, with an electric motor at the center, whose shaft is also the wheel spindle. The stand should be equipped with adequate wheel guards, to protect the operator against wheel breakage, and which can at the same time act as dust hoods if properly connected to an exhaust system. Castings weighing from 2 to 50 pounds are usually snagged on floor stands. For smaller pieces weighing two pounds, or less, it is more economical to use bench stands. They are similar in construction in every way to floor stands, but are smaller and have no pedestal.

GRINDERS, PORTABLE CLASS. Grinders which may properly be included in the portable class are made in quite a variety of forms.

A type which is used for many different purposes is commonly known as a "toolpost grinder," owing to the fact that it is held in the toolpost of a machine like the lathe, planer, or shaper. Modern grinders of this class are electrically driven, the motor being connected directly in the grinding wheel. The current is supplied ordinarily from a lamp socket, connections being made with an ordinary lamp cord. These toolpost grinders are very often used for truing lathe centers, grinding small work in lathes (when a regular grinding machine is not available), and they also enable the planer or shaper to be used for grinding plane surfaces. When used for this purpose, the grinder is clamped in the toolpost in such a position that the axis of the grinding wheel is parallel with the surface to be ground, and the revolving wheel is used in practically the same way that a tool would be used for planing. Some portable grinders have grinding wheels which are driven either by a motor or belt pulley through a flexible shaft, so that the wheel may be guided by hand and be applied to the work at any angle. These flexible-shaft grinders of small sizes are useful for finishing

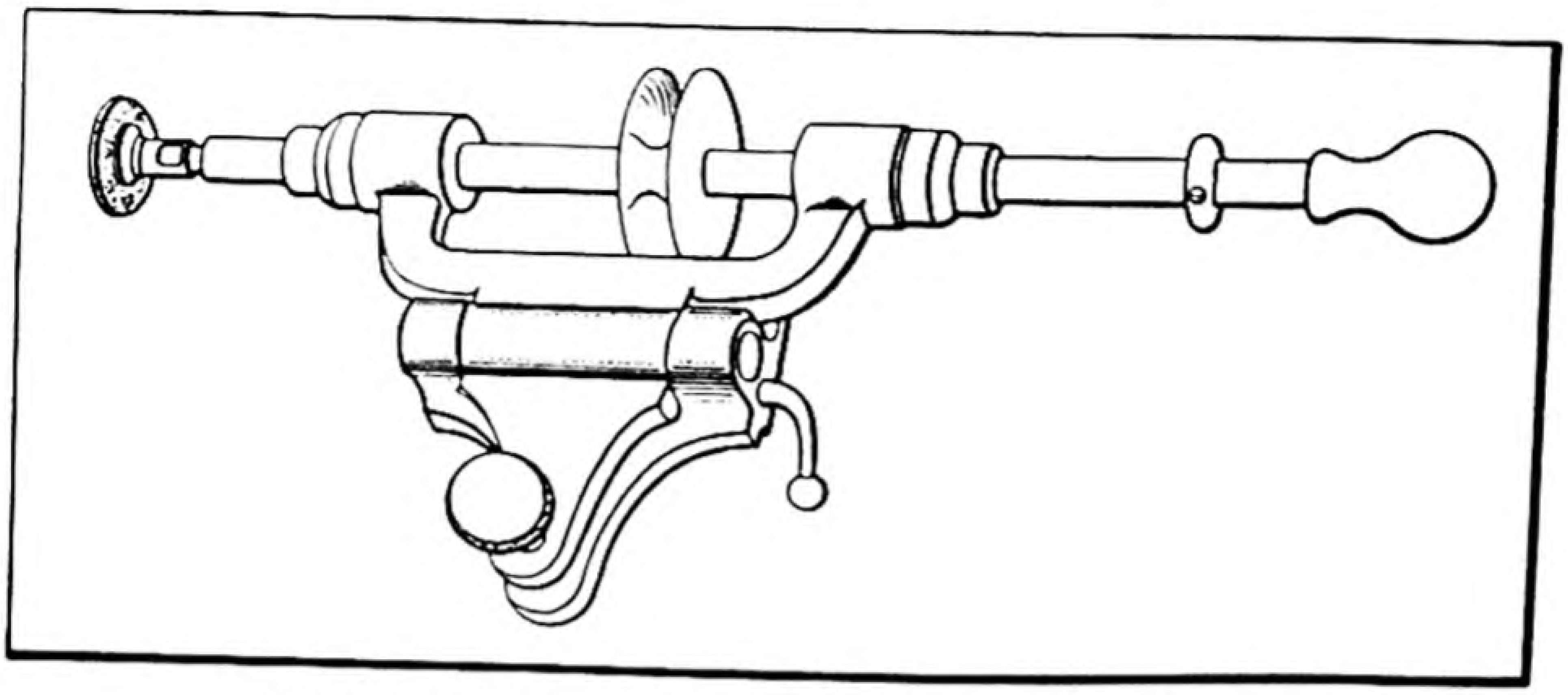
depressions in drop-forging dies, openings in blanking dies, for finishing surfaces on metal patterns, and for many similar purposes. Larger sizes of the flexible-shaft grinders are equipped with a motor mounted on a truck for convenience in moving the grinder from one place to another; grinders of this class are especially adapted for snagging heavy castings in the foundry.

GRINDERS, SWING-FRAME TYPE. The swing-frame grinding machine was designed for the purpose of removing the fins, gates and nails left by and in molding, from castings too heavy to be conveniently lifted by hand. One wheel only is mounted on a machine, and the arm on which the wheel is mounted has a large radius of swing, as well as being designed to travel laterally on a track. Swing frame machines are the heavy-duty machines in the foundry and are rigidly constructed. Great pressures of wheel on work are possible because the operator bears his whole weight at times on the handles of the machine. Wheels from 12 to 18 inches in diameter and from 2 to 3 inches thick are commonly employed.

GRINDING ALLOWANCES. The amount of stock that can economically be removed by grinding depends largely upon the size and power of the grinding machine. The modern practice, when using heavy machines, is to reduce the work in a lathe to within somewhere between $\frac{1}{64}$ and $\frac{1}{32}$ inch of the required diameter and then finish by grinding. The lathe is simply used for roughing, and the stock is removed by taking one or more coarse cuts, leaving a rough surface on the work. It is practicable, in many cases, to grind bar stock from the rough without any preliminary turning operation, although most work is first turned. In using a light grinder, the allowance for grinding must be comparatively small and is governed more or less, in any case, by the size and character of the work, as well as by the power and stock-removing capacity of the grinding machine. The grinding allowance for parts which have to be hardened naturally depends, to some extent, upon the shape of the part and the liability of distortion due to the hardening process.

GRINDING ATTACHMENTS, PUSH-SPINDLE. As the bench lathe is used almost exclusively for fine precision work, it is necessary, in many cases, to finish bored holes and exterior surfaces by grinding. A typical design of an internal grinding attachment for the bench lathe is shown by the illustration. The spindle, which is free to move in a lengthwise direction is held by two bearings, and, when grinding, it is traversed by hand. This device is sometimes called a *push-spindle grinding attachment.* The spindle is driven by a round belt from an overhead countershaft. The handle at the end of the spindle, which is simply a loose knob, is usually held between the thumb and the index finger, and the sensitive touch

secured in this way enables a skilled workman to determine if he is working under proper conditions, as soon as the wheel comes into contact with the work.



Push- or Traverse-spindle Grinding Attachment

GRINDING ATTACHMENT, TOOLPOST. This type of grinding attachment is used on lathes for light grinding operations and also for very light milling or other machining operations on gages, jigs, dies, etc. The attachment is held by a shank that is clamped in the regular toolpost and its spindle is driven either directly by a small motor or by a belt transmission.

GRINDING, FIXED-WHEEL. See Fixed-wheel Grinding.

GRINDING, FORM. See Form Grinding.

GRINDING MACHINES. Grinding machines were used originally almost exclusively for truing tool steel parts which had been distorted by hardening, and are still indispensable for work of this class. The great improvements which have been made, both in grinding machines and abrasive wheels, however, have resulted in the application of the grinding process to the finishing of a great many unhardened parts. In either case, the work, as a rule, is first reduced to nearly the required size by turning in some form of lathe, and then it is ground to the finished dimension. After a part has been hardened, grinding is the only practicable method of truing it. On the other hand, unhardened pieces can be finished by other means, but grinding is preferable for most cylindrical work, because it enables parts to be finished accurately to a given diameter in less time than would be required by any other known method. Many different types of grinding machines have been developed for handling the various kinds of work to which the grinding process is applicable. The machines used for grinding cylindrical parts, such as shafts, piston-rods, etc., are called *cylindrical grinders*, whereas the type used for grinding holes in bushings, gears, milling cutters, etc., are known as *internal grinders*. There are also *surface grinders* for finishing flat or plane surfaces, and, in addition, types

that are designed for specific kinds of work. The first commercial grinding machine, built in 1864–1865, was used only as a precision machine for grinding hardened parts and correcting slight errors due to warping in hardening. From this small beginning, the grinding machine has passed through a remarkable development. See type of machine as, for example, Cylindrical Grinding Machines; Cylinder Grinder; Centerless Grinder; Disk Grinders; Internal Grinding Machines; Surface Grinding Machines.

GRINDING, PLUNGE-CUT. See Plunge-cut Grinding.

GRINDING WHEEL BONDING PROCESSES. See Bonding Processes for Grinding Wheels.

GRINDING WHEEL BUSHINGS. Most grinding wheels are bushed to size with lead, babbitt, or other soft material, the exception being very small wheels, and very large wheels which are to be held in a chuck or in some way other than by flanges on a spindle. The bushing process follows that of truing. The bushing must be true with the sides of the wheel, otherwise the wheel may break when placed on the spindle and the flanges tightened. The diameter of the hole should be from 0.002 inch to 0.005 inch larger than the diameter of the spindle on which the wheel is to be mounted. If the hole is smaller, breakage may occur by forcing the wheel. If the hole is larger than this limit it is difficult to mount the wheel so that it will run true and straight, and, too, it may be clamped in the flanges in such a position as to be out of balance. Lead is the most commonly used material for bushing. Babbitt, being a little harder, is better for the severe duty to which coarse wheels and large cup wheels are subjected. If the lead is too soft, the bushing will not retain its shape and will be easily damaged in mounting.

GRINDING WHEEL CARE. Wheels used in wet grinding should not be allowed to stand partly immersed in water. The water-soaked portion may throw the wheel dangerously out of balance. All wet tool grinders that are not so designed as to provide a constant supply of fresh water should be thoroughly drained at the end of each day's work, and a fresh supply of water provided just before starting.

GRINDING WHEEL COLORS. The color of both aluminum-oxide and silicon-carbide grinding wheels depends on the material used to hold the abrasive particles together, which is termed the "bond." The exact shade, however, is likely to vary somewhat with wheels of the same bond that are produced in the same heat, and so a slight variation in the shade of two wheels does not necessarily indicate a difference in grade. The four most important bonding processes are known as the vitrified, silicate, elastic, and rubber processes, and these names are applied to the grinding wheels

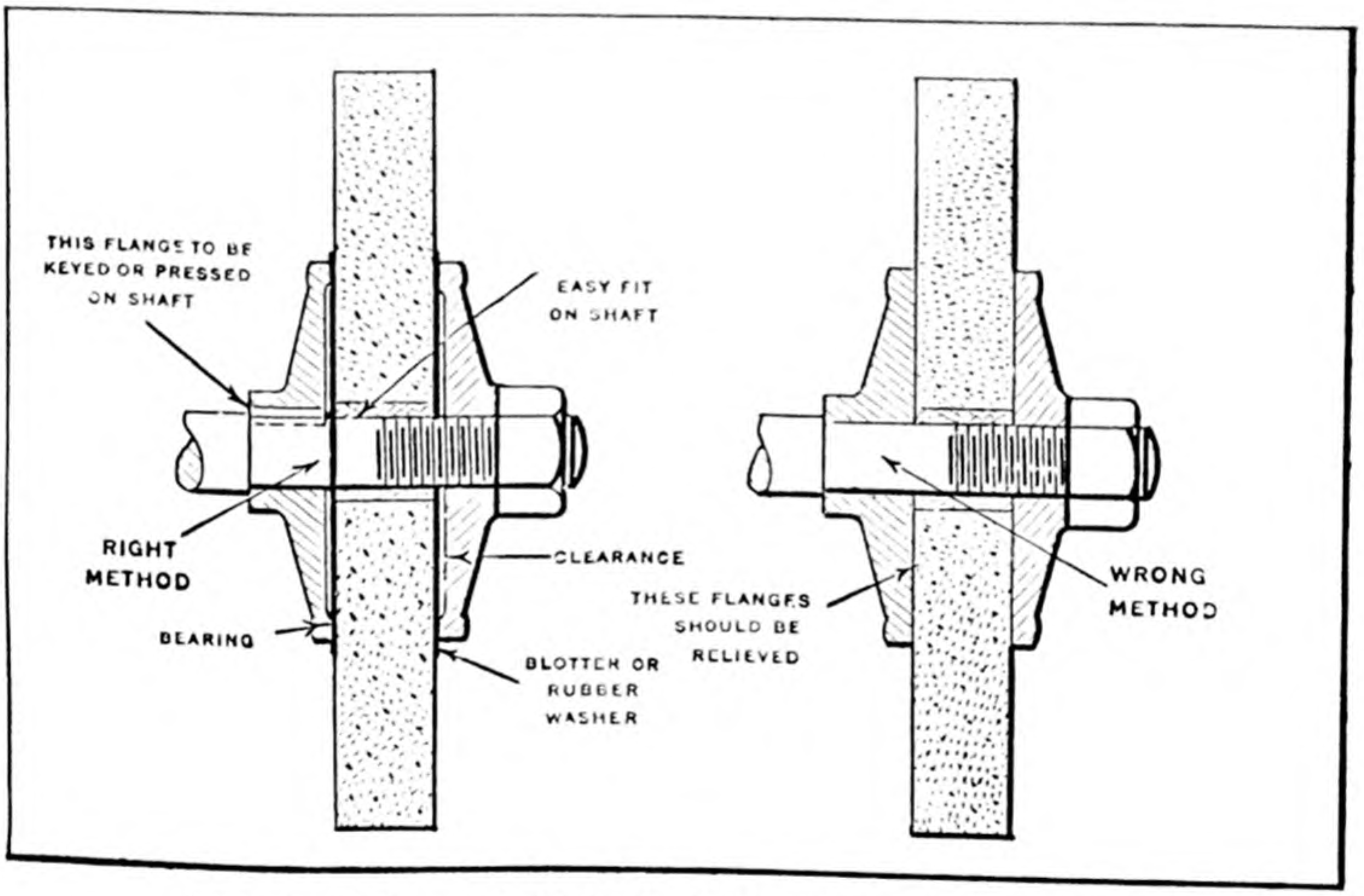
produced by them. The use of different bonds permits the manufacture of wheels of different characteristics to suit all classes of grinding. Vitrified wheels are standard for most grinding operations, the other kinds being used when special conditions are encountered. Probably 80 per cent of all grinding wheels are vitrified. Vitrified wheels can be readily distinguished from the other wheels by their reddish or reddish-brown color, and the clean ringing sound which results when they are tapped. Silicate wheels are easily recognized by their light gray color. Elastic and vulcanized wheels are almost black, but they may be distinguished by their odor when subjected to the friction of a grinding operation or when a small part is burned. Elastic wheels emit an aroma, whereas rubber wheels give off the odor of burning rubber.

GRINDING WHEEL GRADE AND GRAIN. The term "grade," as applied to a grinding wheel, refers to the tenacity with which the bond holds the cutting particles or abrasive grains in place, and not to the hardness of the abrasive. A wheel from which the abrasive grains can easily be dislodged is called "soft," or of "soft grade," and one which holds the grains securely is referred to as a "hard wheel." By varying the amount and composition of the bond, wheels of different grades are obtained. The grade is designated either by letters of the alphabet or numbers. According to the system employed by several manufacturers, the letter M represents a medium grade, and the successive order of letters preceding and following M denotes softer and harder wheels, or *vice versa.* This method of grading wheels is not universal, as a standard system has not, up to the present time, been adopted. The grain or coarseness of a wheel is designated by numbers which indicate the number of meshes to the inch through which the kernels of the abrasive material will pass. For example, a 36 grain means that the abrasive will pass through a sieve having 36 meshes to the linear inch. Many modern grinding wheels are composed of abrasive grains of different size, thus forming what is known as a *combination wheel.* For instance, a No. 36 combination wheel is one having a No. 36 abrasive as the base and a certain percentage of some finer abrasive. These wheels are compact and stronger than "straight grain" wheels.

GRINDING WHEEL MOUNTING. Grinding wheels should fit freely on their spindles but without unnecessary play. If a wheel is forced onto the spindle, there is danger of starting cracks. The diameter of the flanges should be one-half the wheel diameter (never less than one-third), and the flanges should be relieved or recessed to secure an annular bearing at their circumference. (See illustration.) The inner flange should be keyed or shrunk onto the spindle. Compressible washers of blotting paper or rubber should be placed between the wheel and the flanges, to distribute the clamp-

ing pressure evenly. The flanges should be clamped just tight enough to hold the wheel firmly. Wheels should be carefully inspected, and be tapped lightly before mounting, as new wheels occasionally burst when first brought up to speed, because of hidden cracks resulting from rough handling in transit.

The right and wrong methods of mounting grinding wheels are shown by the illustration. The right method requires the use of relieved flanges with compressible washers between the wheel and flange. The relieved flanges give a bearing on the outer edge and the washers distribute the pressure evenly when the flanges are tightened, by compensating for any imperfections or unevenness in either wheel or flange. When the flanges



Correct and Incorrect Methods of Mounting Grinding Wheels

are straight and no washers are used, tightening the spindle nut tends to concentrate the pressure near the center of the wheel instead of distributing it over the entire flange surface, thus creating a dangerous condition. The hole through the wheel bushing should be about 0.005 inch larger than the size of the spindle so that the wheel will slide on without cramping, but still have a fairly good fit on the spindle as well as against the inside flange.

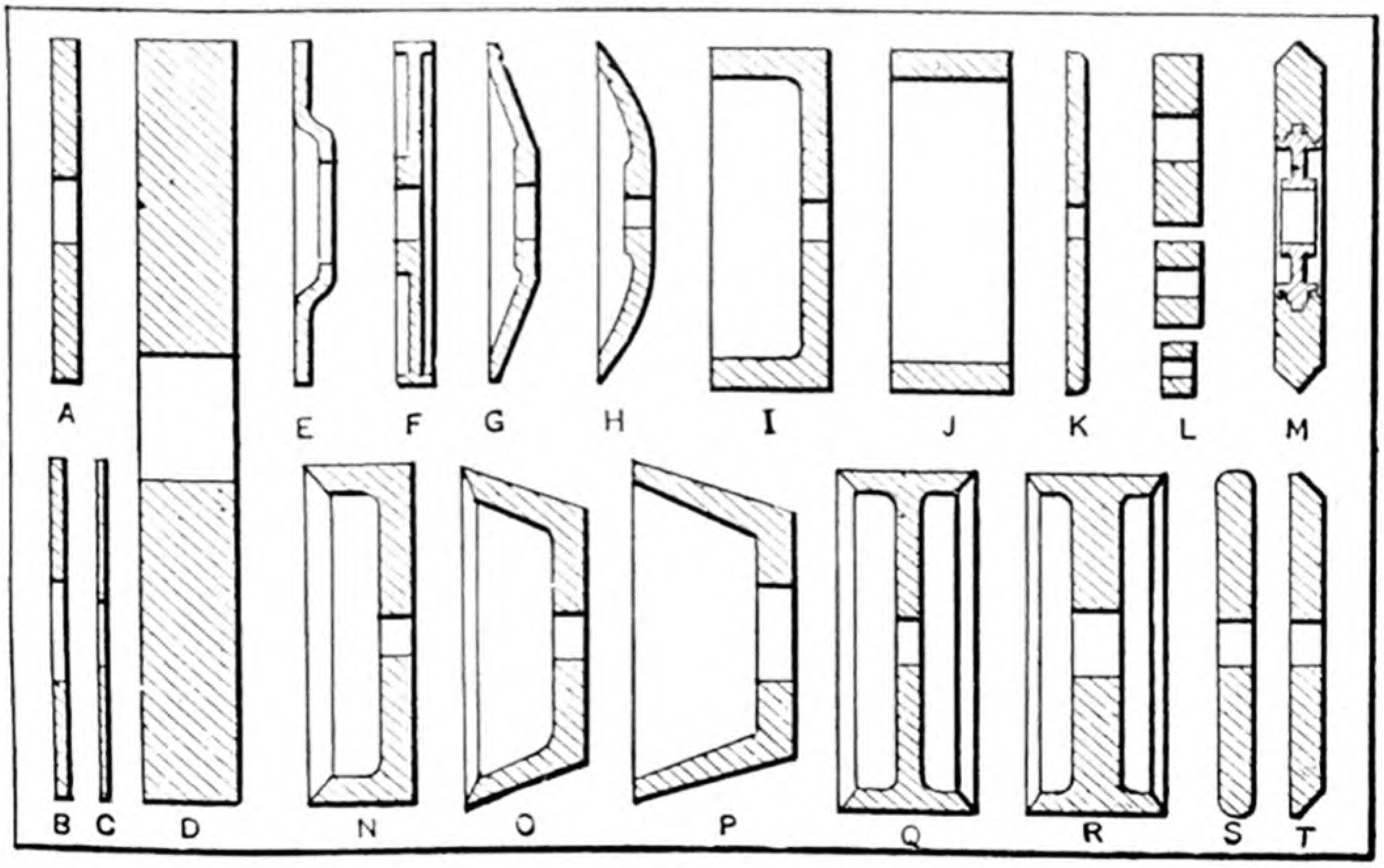
Ends of grinder spindles should be so threaded that the nuts on both ends will tend to tighten as the spindles revolve. Care should be taken in setting up machines to see that the spindles are arranged to revolve in the proper direction, or else the nuts on the ends will loosen. To remove

the nuts, they should both be turned in the direction in which the spindle revolves when the wheel is in operation.

GRINDING WHEEL SELECTION. In selecting wheels for grinding metals, the physical properties of the metals to be ground serve as a basis for determining whether to use silicon carbide abrasives or the aluminous abrasives. (For information about these two general classes see Abrasives.) The silicon carbide abrasives represented by crystolon, carborundum, etc., differ materially from the aluminous abrasives such as alundum, aloxite, etc. The grains of the former are harder but are also more brittle due to the structure; the grains of the latter, while not as hard, are tougher and do not break apart as easily, thus being able to withstand a greater stress. In addition, the aluminous abrasives admit of a certain range of toughness in their manufacture. On account of the difference in physical characteristics of the two abrasives, a general rule has been established, namely, that aluminous abrasives are used for grinding materials of high tensile strength, and silicon carbide abrasives for those of lower tensile strength. While tensile strength alone is not the criterion, inasmuch as hardness and ductility influence the selection, experience has shown that, in general, the aluminous abrasives are particularly adopted for grinding materials of high tensile strength. For information about different grinding wheels, see kind of wheel as, for example, Elastic Grinding Wheels; Vitrified Grinding Wheels; Vulcanite Grinding Wheels

GRINDING WHEEL SHAPES. Grinding wheels are made in a great many different shapes and sizes for use in different types of grinding machines and on different classes of work. Plain disk-shaped wheels similar to those illustrated at *A*, *B*, and *D* (see illustration) are the kind generally used in connection with cylindrical grinding operations. Wheels of this form vary greatly in size, the diameter and width of face naturally depending upon the class of work for which the wheel is used and the size and power of the grinding machine. Very thin or narrow wheels *C* are sometimes used in connection with cutter or reamer grinding, or for cutting off stock. The form of wheel shown at *E* is intended for grinding up to a large shoulder. The wheel is mounted on the end of the spindle and is "dished" at the center so that the retaining nut on the spindle will not project beyond the side of the wheel and strike the shoulder. Wheel *F* is especially adapted for facing the ends of bushings or small shoulders. When the wheel is used for end facing, the grinding is done on the side which is recessed to reduce the contact area to a narrow surface. The saucer or dish-shaped wheels *G* and *H* are extensively used for grinding formed milling cutters, etc., especially on regular tool- and cutter-grinding machines. The cup-wheel *I* is used for grinding flat surfaces by traversing the work

past the end or face of the wheel. The cylindrical or ring-wheel *J* is also used for producing flat surfaces, the grinding being done by the end the same as with a cup-wheel. The latter is attached directly to the spindle, but the ring-type of wheel is held in a special chuck. The special form of wheel shown at *K* is used for thinning the points of twist drills when, as the result of repeated grinding, the web at the point becomes too thick, thus increasing the pressure required to force the drill through the metal. The small wheels shown at *L* are used in connection with internal grinding. These wheels, like all of those shown in the illustration, vary considerably in size, the diameter in any case depending upon the size of the work. The wheels illustrated at *M*, *N*, *O*, *P*, *Q*, and *R*, are employed in connection



Various Commercial Shapes of Grinding Wheels

with a variety of grinding operations on tool- and cutter-grinding machines, whereas wheels *S* and *T* are employed for saw-gumming. Grinding wheels are made in many other shapes, but most of them are modifications of the forms referred to.

GRINDING WHEEL SPEEDS. The peripheral speed of a grinding wheel is usually between 5500 and 6000 feet per minute, but speeds varying from 5000 to 7000 feet per minute are employed. Plain grinding wheels may safely be operated at higher speeds than cup-wheels or those of special shapes; hard wheels may also be run at a higher speed than soft ones. It is the custom of grinding wheel manufacturers to attach a label to each wheel indicating the safe maximum speed for that particular shape and grade of wheel. These recommended speeds should never be exceeded. A com-

mittee appointed by representative abrasive wheel manufacturers, in order to determine safe practices in the use of grinding wheels, recommended the following speeds: A peripheral speed of 5000 feet per minute for vitrified and silicate straight wheels, tapered wheels, and shapes other than those known as cup- and cylinder-wheels, which are used on bench, floor, swing-frame, and other machines for rough-grinding. Speeds exceeding 5000 feet may be used upon the recommendation of the wheel manufacturer, but in no case should a speed of 6500 feet per minute be exceeded. A speed of 4500 feet per minute was recommended as the standard operating speed for silicate and vitrified wheels of the cup and cylinder shape, used on bench, floor, swing-frame, and other machines for rough-grinding. For elastic, vulcanite, and wheels having other organic bonds, the recommendations of individual wheel manufacturers should be followed.

Affect of Work on Wheel Speed. — To a certain extent, the cutting action of an abrasive may be compared with that of a milling cutter. On hard materials having a high percentage of carbon, the wheel must be operated at a lower speed than on soft steel. In general, the softer the metal, the higher may be the speed of the wheel. The high speed reduces, to a considerable extent, the tendency of the wheel to load. In cases where the work revolves during the grinding operation, the speed of the work must be taken into consideration. For example, if the work is revolved at too high a speed, while the wheel runs at the proper speed, the stress on the cutting grains of the wheel caused by the pressure of the work will be materially increased and may tear the grains from the surface of the wheel and decrease the production per wheel.

If the wheel is operating at too high a speed and the work is revolving at the proper speed, glazing will take place rapidly. Again, with the wheel operating at the proper speed and the work at too low a speed, the abrasive will soon be dulled, thus necessitating frequent dressing of the wheel surface. This happens because there is not sufficient action between the work and the wheel to remove the dulled abrasive particles or break them up so that they will present new cutting points. Obviously, production is materially reduced under these conditions.

When a wheel of the most desirable grade for a particular job is not obtainable, a less desirable wheel can sometimes be used with good results if it is run at the proper speed. For example, a soft wheel may be made to act more like a hard one by increasing its speed. A coarse-grain wheel will produce a reasonably smooth surface by increasing its speed, so long as none of the undesirable conditions described are experienced.

GRINDING WHEEL STANDARDS. The Grinding Wheel Manufacturers' Association of the United States and Canada adopted a series of standard shapes and sizes of grinding wheels for various classes of work.

By the elimination of inactive sizes (arrived at from the actual sales records of a number of manufacturers) only the popular selling sizes were considered. From these a composite shape was designed, which should meet present-day machine requirements and satisfy the grinding wheel manufacturers. In this way internal wheels, dish wheels, straight wheels, flaring cups, and double cups were simplified, and fourteen standard types were adopted that are representative of practically all grinding wheels used on standard makes of grinding machines.

The types of wheels are numbered from 1 to 14, and each dimension is designated by a letter. This classification of grinding wheels greatly simplifies the stocking of wheels, and also enables the user to order a grinding wheel by giving the type number and the complete dimensions for such a wheel as designated by its cross-section. Among the fourteen standard types are: Straight wheels for cylindrical grinding; straight wheels, with single and double recesses, for cylindrical grinding; straight wheels, and straight single-recess wheels for internal grinding; cutting-off wheels; flaring cup wheels; straight cup wheels for tool room grinding; straight cup wheels for general use; double-cup wheels; dish wheels; offset wheels; and cylinder wheels.

GRINDING WHEEL TRUING. See Diamonds for Wheel Truing.

GRINDSTONES. Most of the grindstones used in the United States come from Huron, Mich.; Berea, Ohio; or from Grindstone Island, Nova Scotia. All of these localities produce several grades. Most Berea stones are rather coarse; those from Nova Scotia are of all grades. Grindstones are natural sand stones, and the cutting material is oxide of silicon (SiO_2), or quartz sand, as it is commonly called. Grindstones are softer when wet than when dry, and they should never be left standing with one side in the water, because, when the stone is again used, this side will be worn away faster than the other.

Mounting. — The tendency for cracks to start in grindstones can be overcome by a proper method of mounting. It is good practice to fill the central space around the arbor with cement or lead after the stone is centered. Wooden wedges should never be used. The stone should be supported by flanges of generous proportions, and wooden washers from ½ to 1 inch in thickness (or a double thickness of leather or rubber) should be inserted between the flanges and the stone to compensate for surface inequalities.

Speeds. — The grindstones used in machine shops usually have a surface speed varying from 800 to 1000 feet per minute, although these speeds are exceeded considerably in some instances. Cutlery concerns sometimes run grindstones at 3000 or 4000 feet per minute. The safe maximum

speed is difficult to determine, because stones from the same quarry vary in strength. As a rule, the speed should be limited to 2500 feet per minute, if the variety of the stone is not known.

GRIP SOCKET. This is a type of drill socket designed to hold and drive taper shank drills and other tools provided with taper shanks. A groove is milled in the shank of the drill or tool, and a key is let into the body of the socket which fits into the groove and is locked securely in place by turning a revolving collar one revolution. When the key is locked, it is impossible for the tool to slip in the socket or to be pulled out until the collar is turned back again to release the key. In the grip socket, the taper shank is not depended upon to act as a driver, but the key takes the thrust.

GROOVING. In boilers, grooving is a condition similar to "pitting," consisting of the formation of grooves in the boiler plates. It is an injury especially dangerous because the grooves may become covered with scale and are, therefore, difficult to locate. It is caused partly by chemical action from oxygen and chlorine released from the feed water, and partly by mechanical action, such as excessive calking, which impairs the surface of the metal and exposes it to the corrosive elements in the feed water.

GROUND STONE. What is known as "ground stone" is used by some small tool manufacturers for lapping plug gages, ring gages, etc., and this material is also used, to some extent, in connection with watch manufacture, for fine lapping operations. "Hindostan powder" is produced from a very fine sandstone which is quarried in Indiana. Another ground stone known as "Turkey powder" is composed of pulverized Turkish oilstones, which are imported. An expensive grade of ground stone is known as "Arkansas powder;" it is pulverized Arkansas rock and is quarried in Arkansas. The Turkey powder and Arkansas powder have been used quite extensively in connection with watch manufacture.

GUEST'S FORMULA. A formula known as "Guest's formula" was proposed in 1900 by J. J. Guest as the results of experiments made by him on combined bending and torsion. According to this formula:

$$\text{Combined moment} = \sqrt{M_b^2 + M_t^2} = S_s Z_p.$$

In this formula M_b = maximum bending moment; M_t = maximum torsional moment; S_s = permissible working stress in shear; Z_p = polar section modulus. This empirical formula is applicable to parts of circular cross-section and when such material as mild (machine) steel is used.

GULDINUS RULES. The Guldinus or Pappus rules provide a means by which the area of any surface of revolution and the volume of any solid

of revolution may be found. Briefly stated, these rules are: 1. The area of the surface generated by any line rotating about a fixed axis of revolution equals the length of the line multiplied by the length of the path of its center of gravity. The generating line must lie wholly on one side of the axis of revolution and must be in the same plane as the axis. 2. The volume of a solid body formed by the revolution of a surface about a fixed axis equals the area of the surface multiplied by the length of the path of its center of gravity. The surface must lie wholly on one side of the axis of revolution and must be in the same plane as the axis.

GULLETING FILE. This file is made of round section in the blunt shape. It is single-cut and used principally for extending the gullets of the teeth of what are known as the "gullet-tooth" and "briar-tooth" saws.

GUN-BRONZE. Gun-bronze is an alloy composed mainly of copper, tin, and zinc. According to the U. S. Navy specifications, it contains from 87 to 89 per cent of copper, from 9 to 11 per cent of tin, from 1 to 3 per cent of zinc, with a maximum of 0.06 per cent of iron and 0.2 per cent of lead

GUNITE. Gunite is a strong wear-resisting cast metal which is used for various machine parts such as cams, rails, and miscellaneous wearing surfaces, and also for locomotive cross-head shoes, cylinder and valve bushings and rings, and for certain automotive parts such as brake drums, clutch pressure plates, etc.

GUN LATHE. Gun lathes are designed for turning or for turning and boring naval and coast defense guns, and are sometimes known as *turning and boring lathes.* Comparatively small lathes of this class, such as are used for turning five- or six-inch guns, are often designed along the same general lines as an engine lathe. The larger lathes, however, differ from the engine lathe, both in regard to the design of the bed, the method of imparting feeding movement to the carriage, etc. These larger sizes usually have three or four shears on the bed, and two tool carriages instead of one.

GUN-METAL. Gun-metal or gun-bronze consists of about 90 per cent of copper and 10 per cent of tin with small percentages of lead, iron, and zinc. Gun-metal is used as a bearing metal and for a great many parts, such as valves, valve seats, flanged pipe fittings, etc., where exposed to the action of sea water. The composition called for by the United States Navy specifications is: Copper, from 87 to 89 per cent; tin, from 9 to 11 per cent; zinc, from 1 to 3 per cent; iron, not exceeding 0.06 per cent; and lead, not exceeding 0.2 per cent. The mixture formed of copper, 88 per cent; tin, 10 per cent; and zinc, 2 per cent, is variously known as

"zinc bronze," "Admiralty metal," "government-bronze," and "88–10–2 alloy," although these terms are also frequently applied to all gun-metals. The castings made from gun-bronze are improved by the addition of a small amount of zinc, and the alloy is made harder by the presence of a small percentage of iron, while the small percentage of lead present makes an alloy that is more easily machined. The tensile strength of gun-bronze is from 25,000 to 35,000 pounds per square inch. The elastic limit varies from about 15,000 to 17,000 pounds per square inch, and the metal withstands severe shocks without fracture. The minimum elongation should be about 15 per cent in two inches.

GUN-METAL FINISH ON ALUMINUM. The gun-metal finish can be given aluminum by immersing it for from six to ten seconds in a cold solution of 12 parts of hydrochloric acid; 1 part of chloride of antimony; and 87 parts of distilled water. After that, thoroughly wash it in running water for several minutes, dry with heat, and lightly buff with a high-speed wheel. The color penetrates the metal and its depth is governed by the length of time it is immersed. If immersed longer than ten seconds, the solution should be weakened, as hydrochloric acid "eats" the metal.

GUN-METAL FINISH ON STEEL. The first operation in obtaining a gun-metal finish is to thoroughly clean the work by methods that will not injure the surfaces. Grease and dirt are readily removed by boiling the work in a solution of one pound of potash to one gallon of water. The potash will last a long time and the water can be replenished as it boils away. When exhausted, the bath can be renewed by adding fresh potash. Scale, oxide, etc., are not removed by washing methods and, hence, a pickling in acid solutions is required. Polished steel surfaces can be pickled by immersing them, in contact with a piece of clean zinc, in a moderately strong solution of the acid potassium sulphate and water. Hydrogen gas is liberated when the zinc decomposes the solution, and this removes the oxide of iron or rust from the steel. Another good pickling solution for steel is made of 20 parts of hydrochloric acid and 80 parts of water. Iron and steel can also be pickled white, in concentrated nitric acid to which has been added some lampblack. After pickling, the work should always be thoroughly washed and scratch-brushed.

Solutions for Gun-metal Finishes. — Several different chemical solutions have been used successfully in giving steel the gun-metal finish or black color. Among these are the following: Bismuth chloride, 1 part; copper chloride, 1 part; mercury chloride, 2 parts; hydrochloric acid, 6 parts; and water, 50 parts. Ferric chloride, 1 part; alcohol, 8 parts; and water, 8 parts. Copper sulphate, 2 parts; hydrochloric acid, 3 parts; nitric acid, 7 parts; and perchloride of iron, 88 parts. Other solutions have been

prepared from nitric ether, nitric acid, copper sulphate, iron chloride, alcohol and water, and from nitric acid, copper sulphate, iron chloride, and water.

The method of applying these solutions and finishing the work is practically the same in all cases. The surface of the work is given a very thin coating with a soft brush or sponge that has been well squeezed, and is then allowed to dry. If put on too thick the surface will be unevenly corroded and white spots will appear. The work is then put into a closed retort to which steam is admitted and maintained at a temperature of about 100 degrees F. until covered with a slight rust. It is then boiled in clean water for about fifteen minutes and allowed to dry. A coating of black oxide will cover the surface, and this is scratch-brushed. After brushing, the surface will show a grayish black. By repeating the sponging, steaming, and brushing operations several times, a shiny black surface will be obtained that is lasting. For the best finishes these operations are repeated as many as eight times.

GUNTER'S CHAIN. Gunter's chain is a chain used by surveyors for land measurements. It has 100 links, each 7.92 inches long. The total length of the chain is 66 feet, or 4 rods. The handles and the center of the chain are fitted with swivels to prevent kinking. At every tenth link from either end is attached a brass tag with one, two, three, or four prongs to assist in the reading of the measurements. The fifty-link mark is round, so as to be easily distinguished from the others. This chain is not used as much as formerly. See also Engineer's Chain.

GURLEY'S BRONZE. Gurley's bronze is used for the framework for surveyors' instruments, and similar purposes. It contains 16 parts of copper; 1 part of tin; 1 part of zinc; and ½ part of lead. The tensile strength is about 40,000 pounds per square inch; the elongation, about 25 per cent in 2 inches; and the specific gravity, about 8.7.

GUTTA-PERCHA. Gutta-percha is derived from the secretions of the bark of certain trees found in the Straits Settlements and the Malaccan Archipelago. At temperatures between 32 and 80 degrees F., it resembles dark brown leather; at temperatures above 80 degrees F., it softens; and at 150 degrees F., it becomes plastic and can be molded. Upon cooling, it again becomes non-plastic. It oxidizes when exposed to the air, changing its color and becoming brittle. The chief use of gutta-percha is for electrical insulating purposes. It appears in commerce in the forms of blocks or cakes of a grayish appearance. When used for insulation, it is shredded into warm water, kneaded, strained, and rolled into sheets. It is applied to the wire that is to be insulated by special tubing machines, or wound upon the wire in the form of strips. Gutta-percha may be used as an

insulating material in the pure state, without admixtures of any kind. It is less porous than rubber, and is therefore more waterproof. For this reason, it is the best material to use as an insulation for submarine cables. Its specific gravity is almost exactly equal to that of water.

GYPSUM. Gypsum is a sulphate of lime. It is the same as calcium sulphate, commonly known as plaster-of-paris. See Calcium Sulphate.

GYRATION RADIUS. See Radius of Gyration.

GYROSCOPE. The gyroscope may be defined, in general, as a mechanism in which a rotating wheel or disk is mounted in gimbals so that the principal axis of rotation always passes through a fixed point. The gyroscope possesses the peculiar quality of resisting any angular displacement of its axis after it has once been set in motion; hence, it is used for securing equilibrium in a great number of devices. Gyroscopes are applied as stabilizers. The gyroscope is also used in a special type of gyroscopic compass which has been highly successful.

HACKSAW BLADES. The straight-tooth blade is generally preferred for power hacksaw machines, although hacksaw blades are made with hook teeth and other forms having positive and negative rake. The objection to the hook-tooth blades is that they " hog in " or bury their teeth whenever they come in contact with edges or walls of the work having an acute angle. Blades having negative rake teeth require more pressure in cutting, but they are often of advantage for cutting parts having thin walls, and in general for work that presents little or no resistance to the pressure of the teeth. The most commonly used pitches are 10 and 14 teeth per inch. The 10-pitch blades are used to cut heavy cross-sections, while the 14-pitch blades are used for medium and light work. On the extremely hard materials of small cross-section, where a heavy pressure must be applied, a fine-pitch blade is necessary, so that the pressure can be distributed over enough teeth to prevent the points of the teeth from crumbling under the pressure. On the other hand, in soft metals, blades of a coarser pitch provide chip space for the larger and heavier chips that a heavy-blade pressure produces in the softer metals.

Tests have shown that steel for saw blades should contain from 1.00 to 1.25 per cent carbon, 0.55 to 2.00 per cent tungsten, 0.20 to 0.50 per cent manganese, 0.20 to 0.80 per cent chromium, and about 0.25 per cent vanadium. Another well-known manufacturer of saw blades keeps the carbon content between 0.80 and 0.90 per cent, but increases the tungsten content from 2.00 to 3.60 per cent, thereby obtaining what is claimed to be an unusually tough and hard blade. The high carbon content blades are not so suitable for high tension as the medium carbon blades; but they are often found to cut better under medium pressures and high cutting speeds, while the lower carbon content blades often cut best on materials that call for a heavy feed or pressure, but a medium or low cutting speed.

High-carbon blades are recommended for mild steel, where high speed and medium pressure is used, and the lower carbon blades with higher tungsten content for alloy steels, where medium cutting speed and heavy pressures are used. If a great deal of sawing is done in one class of steel, the maximum cutting speed may be determined as follows: Increase the cutting strokes per minute, by 5 for each piece cut off until the temper is drawn in the blade in spite of the cooling lubricant. Then reduce the cutting strokes per minute, about ten strokes, and the most efficient cutting speed has been obtained.

HACKSAW CUTTING SPEEDS. As the cutting action of a hacksaw is not continuous and the speed is not uniform, the average cutting speed in a power hacksaw machine should be considered. Approximately, the cutting speed of the first and last quarters of the stroke may be assumed to be

one-half the speed of the stroke in the second and third quarters. For example, assume that the hacksaw has a 6-inch stroke. Then the first $1\frac{1}{2}$ inches of blade travel is accomplished at half the speed of the next $1\frac{1}{2}$ inches of travel, which completes half the stroke. The third $1\frac{1}{2}$ inches of blade travel is accomplished at the same speed as the second, and finally the fourth and last $1\frac{1}{2}$ inches of travel is again accomplished at one-half the speed of the two middle fourths; or briefly, the middle 3 inches of the stroke is traveled at an average speed of twice that of the ends, and this is the cutting speed to be reckoned with.

Lay out a half circle, and connect each end of the half circle by its diameter. Divide the arc of the half circle into three equal spaces. Project the division points down to the diameter, and it will be seen that the length of the middle space, measured on the diameter, is twice the length of the end spaces. The two middle fourths of the stroke are traveled in one-third of the half-circle or in one-sixth of the time required for one complete revolution of the crankshaft. Hence, if the saw blade continued to travel at the same cutting speed as it does during the middle three inches of the stroke for an entire revolution of the crankshaft, it would travel six times three inches, or eighteen inches per revolution. From this we obtain the cutting speed in feet per minute as equal to R. P. M. of crankshaft $\times \frac{6 \times 3}{12}$. For example if the crankshaft is running at 100 revolutions per minute, and the stroke is 6 inches, the cutting speed would be 150 feet per minute; at 80 revolutions per minute, it would be 120 feet per minute; and at 50 revolutions per minute, 75 feet per minute. When a given cutting speed in feet is required on a machine having a 6-inch stroke it is only necessary to see that the revolutions per minute of the crankshaft or the cutting strokes per minute equal two-thirds of the cutting speed expressed in feet. Assume that for a given case a cutting speed of 90 feet would be satisfactory, when using a cutting lubricant. Then the cutting strokes per minute with a 6-inch stroke should be 60.

HACKSAW MACHINES. The power hacksaw machine, in its simplest form, merely provided means for reciprocating a hacksaw frame by mechanical power. Gradually, a great many improvements have been made in these machines, until now they constitute a distinct type in the machine tool class. The first improvement made in machines of this kind was to apply weights to give an adequate cutting pressure to the saw blade. The weight of the saw frame, in addition to sliding weights, is today utilized in several power hacksaw machines for obtaining varying pressures on the blade.

Another power hacksaw machine employs a ratchet feed. The blade

pressure is varied by changing the compression of a spring that supplies the power for the ratchet fingers, this change being made through a lever on the side of the machine. Another power hacksaw machine is so designed that the blade pressure is applied mainly from an oil cylinder, the pressure in which is produced by a pump. The saw frame of still another design does not travel downward through an arc, but instead is mounted on a double-bearing slide, so that the blade always travels along parallel lines. The saw frame is brought down by means of a screw and nut mechanism actuated intermittently by a ratchet and pawl. Between the ratchet and the screw is located a friction disk that prevents excessive pressure from being exerted on the blade.

HADFIELD'S STEEL. The steel known as Hadfield's steel contains about 12 per cent of manganese and from 0.8 to 1.25 per cent of carbon. This steel is very ductile and hard. The ductility of the steel is brought out by sudden cooling, the process being opposite to that employed for carbon steel. Hadfield manganese steel is used for car wheels, ore and rock crushers, mining machinery, and, in general, where a steel that will resist abrasion is required. It is very hard and cannot be machined with ordinary tools. Parts made from manganese steel are, therefore, cast and subsequently ground on the finished surfaces.

HAFNIUM. Hafnium is found in all zirconium minerals in amounts ranging from 2 to 20 per cent, and is sufficiently abundant to be available for commercial purposes. It is also present in so-called commercially pure zirconium oxide and salts of zirconium. In chemical properties, it closely resembles zirconium. It has a very high melting point and high power of light emission.

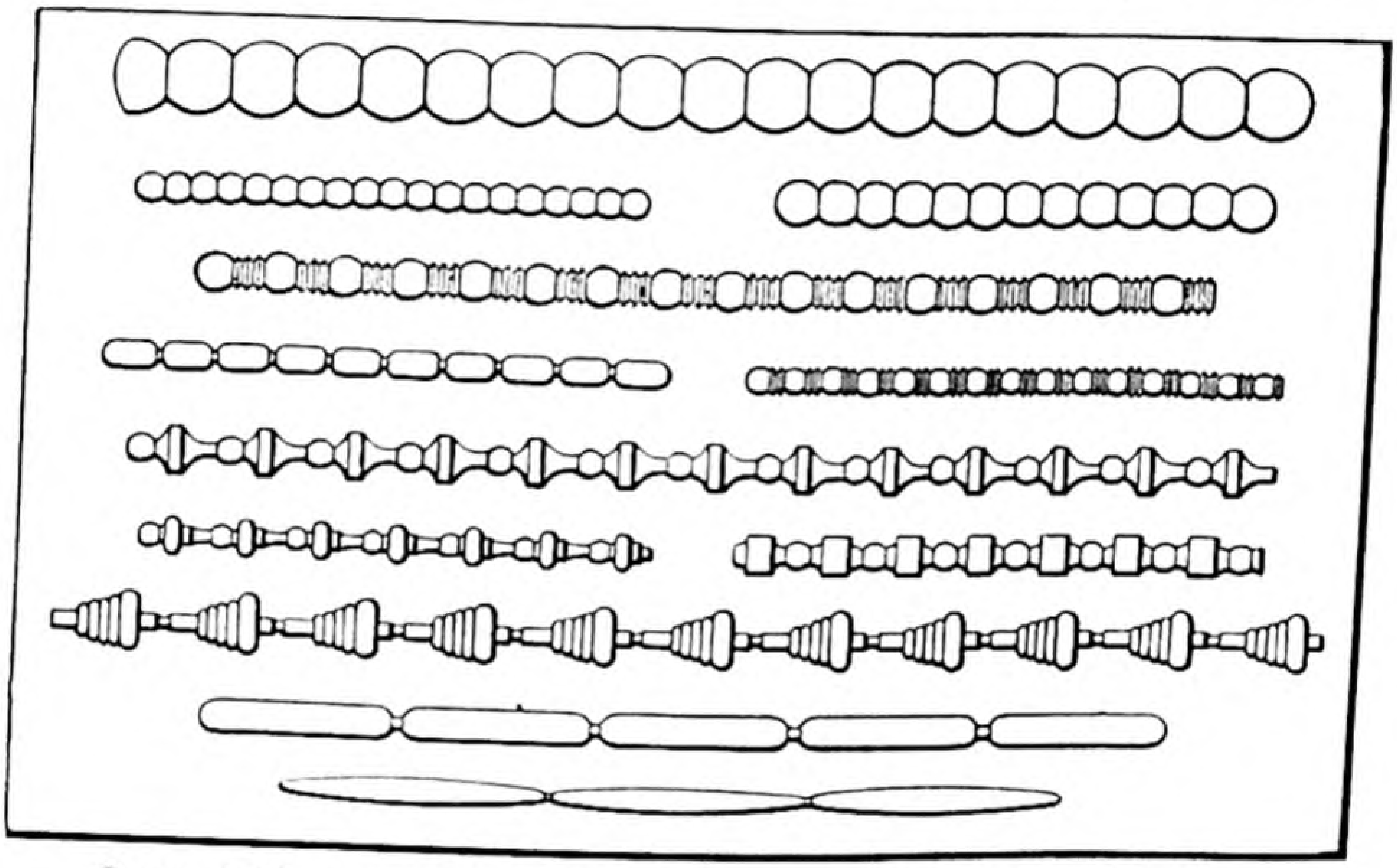
HALF-NUTS. The term "half-nuts" is applied to the two-part nut used on engine lathes for engaging and disengaging with the lead-screw. The half-nuts are opened or closed by a lever and are used to control the movement of the lathe carriage while cutting screw threads.

HALF-OPEN TAILSTOCK. This is a special design of tailstock for bench lathes in which the upper part of the spindle bearing is removed, so that the tailstock spindle may be readily lifted out of place. This tailstock is used on light delicate work when different tools are employed, the open construction enabling the spindle to be rapidly removed or replaced.

HALF-ROUND FILES. Such files do not form a complete semi-circle, as the name implies, the arc being about one-third of the circle. Files of this class are double-cut and mostly bastard, although many are either second-cut, smooth, or dead smooth, the latter being used to a limited extent. Those having teeth finer than bastard are cut single on the convex side.

This type is extensively used in machine shops, especially on curved surfaces.

HAMMERING MACHINES. Machine hammering, a process akin to swaging, plays an important part in the manufacturing processes in the jewelry and allied trades. A greater variety of work may be hammered than it is possible to swage, and, for this reason, the process is adapted to the forming of ornamental shapes, such as beaded work and jewelry parts, either from solid stock or tubing. The advantage of the process over screw machine production is three fold: Less material is required for the work,



General Classes of Work Produced on a Hammering Machine

the resulting product is stronger on account of the compression of the metal, and the surface of the stock is not removed, thus making it possible to work rolled gold-plated wire and tubing. The hammering machine is not a competitor of the screw machine, although many classes of work can be done better by the hammering machine. The illustration conveys an idea of the range of work that may be done on hammering machines, and particularly shows the value of these machines in the optical and kindred trades. The hammering is done by means of two dies, one forming the anvil and the other the hammer proper. As blows are struck the action takes the form of a continuous vibration. On some classes of work, the upper die strikes 3600 blows per minute. In making dies for work that is to be separated, such as small ornaments or beads, the dies are left with a cut-off at one end, so that, as the work is moved forward in the dies, one section will be completed and cut off at each forward movement of the stock. In all hammering dies, each succeeding pair of units of the design is slightly smaller than the previous pair nearer the end where the stock enters, so that each set of sections of

the dies closes the metal down a little more until it is finished by the last set.

HAMMERS, FORGING. Power hammers such as are used for general forging operations may be divided into two general classes: 1. Those which are actuated by a crank or eccentric that imparts motion to the hammer head through some form of mechanism designed to give the required resiliency or springing action. 2. Those which are operated either by steam or compressed air. Hammers of the first class mentioned are commonly designated as *power* hammers in order to distinguish them from *steam* hammers, although they are all operated by power. Many power hammers such as are used on the lighter classes of forging work are of the vertical design.

Hammer Ratings. — Forging hammers are rated in terms of the total weight of the falling or reciprocating parts, including the weight of the ram, piston-rod, piston, and the ram die with its key and dowel. Drop hammers of both steam and air-operated types are rated according to total weight of the ram, piston-rod, and piston, but the dies are not included for hammers of this type. The rating of board drop hammers is based on the total weight of the ram, boards, and the wedges which hold the boards in place in the ram. The weight of the dies is not included in the rating in this type as in other types of drop hammers.

From the foregoing it is evident that if a hammer has a rating of 1 ton this means that the falling or reciprocating parts weigh 2000 pounds, except that the weight of the ram die is omitted in the case of drop hammers. This method of rating hammers does not disclose the energy available, since this is affected by varying speed, stroke, ratio of anvil weight to falling weight, and steam conditions in the case of steam-operated hammers.

HAMMER WEIGHT. The ball peen hammers commonly used by machinists weigh from 1 to $1\frac{1}{2}$ pounds. This weight does not include the handle, which is usually from 12 to 14 inches long and made of hickory.

HAND. Hand is an old length measure, equal to 4 inches.

HAND CHASER. A hand chaser is a type of threading tool used either for cutting or chasing external or internal threads. The tool is supported upon a rest and is guided by the hand; it is used mainly on brass work, for slightly reducing the size of a thread that has been cut either by a die or threading tool. A hand chaser may also be used for truing up battered threads in repair work and for similar purposes.

HAND FILE. This type of file is parallel in thickness from the heel (end of file body next to tang or handle) to the middle, and is tapered, as to thickness, from the middle to the point, the latter being about one-half the

thickness of the stock. The edges of the fire are usually parallel throughout the entire length but are sometimes drawn in slightly at the point. The hand file is ordinarily preferred by machinists for finishing flat surfaces. The teeth are usually double-cut, bastard, although many files of this type have teeth of second-cut, smooth, or dead-smooth.

HAND GRINDING. "Hand grinding" is the term applied to operations where the work to be ground, or the mechanism upon which the wheel is mounted, is held in the hands of the operator. It antedates all other grinding methods and is still used for a large variety of operations, ranging from the grinding of finest tools to the smoothing of large rough castings. The types of machines employed include bench and floor stands, swing frame, flexible shaft, portable electric and pneumatic, and the ordinary wet tool machines for sharpening lathe, planer and other machine shop tools.

HAND-HOLE. In a steam boiler, a hand-hole is an opening that is large enough for the hand and arm to enter the boiler for washing out, for making slight repairs, or for inspection.

"HAND" OF MILLING CUTTERS. A cutter which rotates to the right (clockwise), as viewed from the spindle or rear side, is said to be right-hand, and, inversely, a left-hand cutter is one that turns to the left (counter-clockwise) when viewed from the spindle of the machine.

HAND REAMER. A "hand" reamer is used by hand for producing holes that are to be smooth and true to size. The reamer consists of a cutting portion, a shank, and a square by which it is turned when in use. Between the cutting part and the shank, there is a short neck, the purpose of which is to provide clearance for the grinding wheel when grinding the cutting edges and the shank of the reamer.

HANDSAW FILE. These files have the same section as a "three-square" type but differ in that the edges are given the proper bluntness to insure durability; the three-square files have comparatively sharp edges so that they are entirely unfit for filing saws. While the term "taper" is commonly used to denote a file which tapers in a lengthwise direction toward the point, custom has also established the term "taper" as a short name for the three-square handsaw file. One class of handsaw file is tapered to a small point and the teeth are single-cut, second-cut. These files are very extensively used for sharpening handsaws. Some saw files are double-cut, second-cut, these being preferred by some for filing fine-tooth saws.

HAND SCREW MACHINE. Turret lathes of the screw-machine class are sometimes given names which indicate rather definitely the type of machine; for instance, the name *hand screw machine* is often applied to

turret screw machines in general, in order to distinguish between the hand-operated type and the automatic type; or the term " hand screw machine " may indicate a design not equipped with an automatic feeding mechanism for the turret slide.

HAND TAPS. Hand taps are the most commonly used of all taps. They are usually made in sets of three, termed " taper," " plug," and " bottoming " taps. When all three taps are employed for tapping a hole, they are used in the order named. The term " taper tap," when used to designate the first tap in a set of three hand taps, should not be confused with the term " taper tap " as properly used for a tap the threaded portion of which is conical. The point of a taper tap in a set of hand taps is turned down to the diameter at the bottom of the thread for a length of about three or four threads. This turned-down portion acts as a guide, tending to produce a straight hole. From the upper end of the guide, about six threads are chamfered or tapered until the full diameter of the tap is reached. The remaining part of the threaded portion of the tap is turned straight or parallel. On the plug tap, three or four threads are chamfered at the point, and the remaining portion of the thread is turned parallel. On the bottoming tap, only about one thread is chamfered. The diameter of the straight portion of the thread of all the taps in the set is the same, in the regular type of hand taps. Taps are made in sets, however, in which only the bottoming tap is of the full diameter, while the other taps gradually decrease in diameter, so as to distribute the work between the three taps.

HANGER BOLT. A hanger bolt is one having a lag-screw thread at one end and a regular standard thread at the other end, used for attaching shaft hangers to wooden beams or posts.

HANGERS, SHAFT. See Shaft Hangers.

HARDENING MACHINES. In order to prevent injurious distortion, such as frequently occurs when steel tools or other parts are being cooled for hardening, special " hardening machines " or fixtures are used for some classes of work. A machine or fixture for this purpose is designed ordinarily to hold the work securely between rigid clamping members, and thus prevent warping at the time of plunging in the cooling bath. Another plan is to so design the machine or fixture as to insure uniform cooling. One machine of this type, is arranged to rotate the work rapidly as it is being immersed in the quenching bath. A commercial hardening machine which has been designed primarily for preventing distortion of gears but which may be adapted to other classes of work, is so arranged that the gear to be hardened is confined rigidly between two die-plates during the cooling operation. This machine is pneumatically operated.

HARDENING STEEL. The process of hardening steel consists essentially of heating the steel to the required temperature and quenching it suddenly in some cooling medium. In the actual heating of a piece of steel, several requirements are essential to good hardening: First, that small projections or cutting edges are not heated more rapidly than is the body of the piece, that is, that all parts are heated at the same rate, and second, that all parts are heated to the same temperature. These conditions are facilitated by slow heating, especially when the heated piece is large. A uniform heat, as low in temperature as will give the required hardness, produces the best product. Lack of uniformity in heating causes irregular grain and internal strains, and may even produce surface cracks. A temperature much above the so-called "critical point" of steel (which marks the correct hardening temperature) tends to open its grain — to make it coarse and to diminish its strength — although such a temperature may not be sufficient to lessen appreciably its hardness. The hardening of a carbon steel is the result of a change of internal structure which takes place in the steel when heated properly to a correct temperature.

Critical Temperatures. — The temperatures at which internal changes in the structure of a steel take place are frequently spoken of as the "critical" points. These are different in steels of different carbon contents. The higher the percentage of carbon present, the lower the temperature required to produce the internal change. In other words, the critical points of a high-carbon steel are lower than those of a low-carbon steel. In steels of the commonly used carbon contents, there are two of these critical temperatures, called the *decalescence* point and the *recalescence* point, respectively. A very important feature is that steel containing hardening carbon, *i.e.*, steel above the temperature of decalescence, is non-magnetic. This feature has been taken advantage of as a means of determining the correct hardening temperature, and appliances for its application are on the market. *Harden carbon steel at the lowest possible heat and always on the rising heat.* The grain of the steel corresponds to the highest heat it has received since it was black. If a piece of steel is forged at 1600 degrees F. and allowed to cool down to 1400 degrees F. to harden, it will have a grain corresponding to 1600 degrees F.

HARDENING STEEL BY "CLOUDBURST" PROCESS. The super-hardening of parts by means of the "Cloudburst" process is as follows: A part made of hard steel is immersed in balls which move about at a high velocity, striking each other and the part in rapid succession. This produces a thin super-hardened layer on the part analogous to that obtained on automobile gears and other parts as they become worn in service. It has been found that after the layer has been started, the velocity of the balls can be

increased and this will increase the hardness and thickness of the layer, the layer resisting indentation. The super-hardened layer gradually decreases in hardness throughout its thickness, and as there is no abrupt change in hardness, the layer has no tendency to scale.

The degree of hardness that can thus be produced depends upon the super-hardening capacity of the steel, which is easily measured by means of the "Pendulum" hardness tester. The ball velocity required to produce the hardness is determined by experience. The initial ball velocity is so adjusted to the hardness of the work that it is just enough not to indent the surface. It follows, then, that if any part of the work is soft, its surface will be indented and roughened. This has resulted in a process, by means of which large quantities of hardened articles can be tested for hardness, all at once and all over, without marking them except on soft spots. One "Cloudburst" testing machine makes 200,000 hardness tests per minute.

HARDIE. The *hardie* is a form of chisel for use in conjunction with an anvil. It is made with a square shank to fit the hardie hole in the anvil, and is used for light cutting, such as trimming the ends of small forgings and cutting light stock. The piece to be severed is laid upon the chisel edge of the hardie and is struck with a hammer.

HARDNESS NUMERAL. A number expressing the hardness of a metal when tested by a hardness-testing apparatus is called a hardness numeral. This term is specifically applied to the numbers indicating the hardness when testing by the Brinell hardness-testing method.

HARDNESS SCALE. See Moh's Hardness Scale.

HARDNESS TESTING. See Ballantine Hardness Test; Brinell Hardness Testing; Electromagnetic Hardness Testing; Keep's Test; Pendulum Hardness Tester; Rockwell Hardness Test; Sclerometer; Scleroscope.

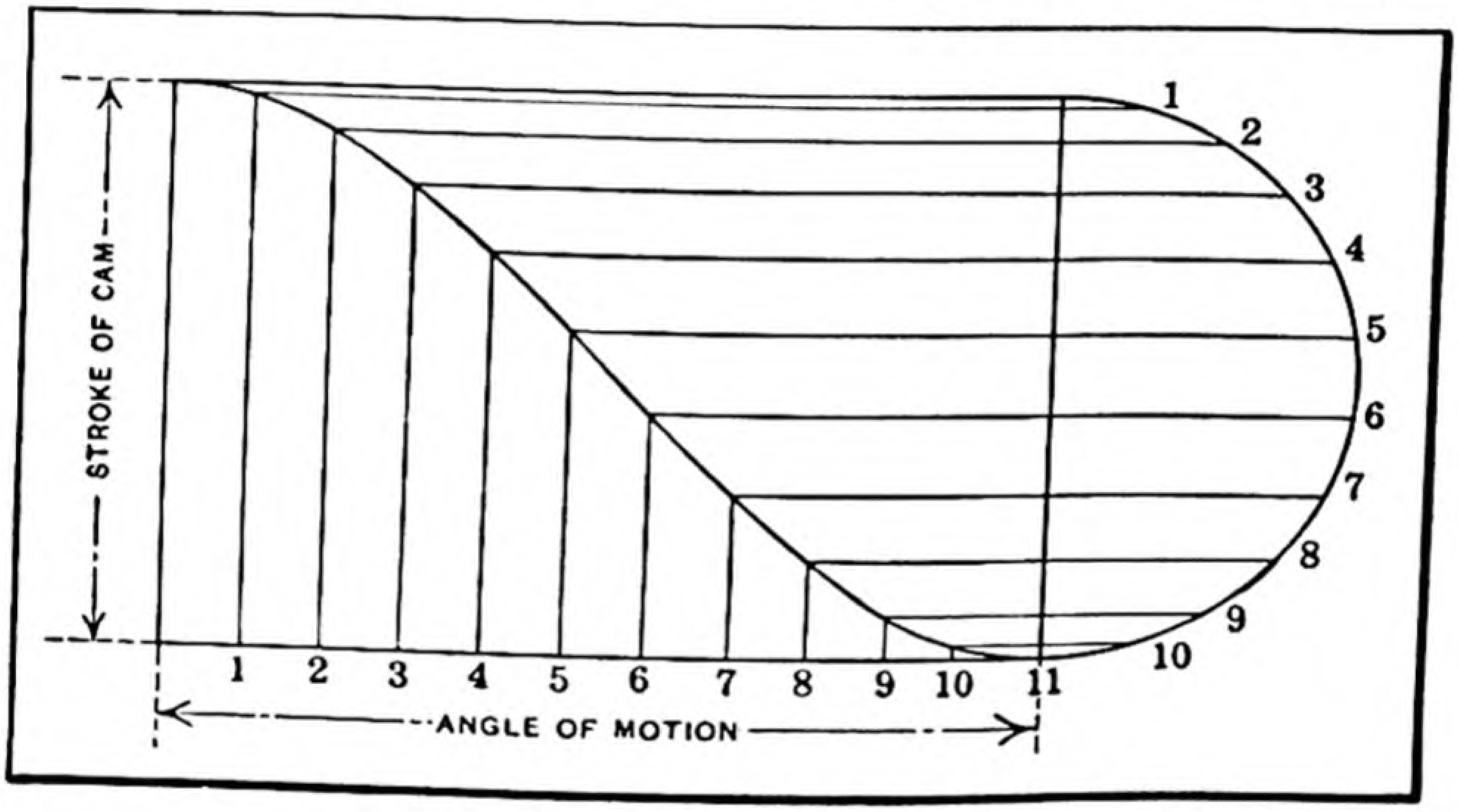
HARD SOLDERS. Hard solders, such as are used for silver soldering, and known as *silver solders*, are composed of silver, copper and zinc or brass; whereas hard solders which are used for brazing are alloys formed of copper and zinc. The hard solder used for brazing is commonly known as *spelter* or *spelter-solder*. The composition of silver solders varies considerably according to the nature of the work. A silver solder extensively used by jewelers contains 70 parts of silver and 30 parts of copper.

HARDWARE BALLS. Hardware or C-grade steel balls are balls which may have a slightly defective surface and which are of poorer quality than the steel balls generally used in machine ball bearings.

HARMONIC. A harmonic, in electricity, is an alternating-current electromotive force wave of higher frequency than the fundamental, and super-

imposed on the same so as to distort it from a true sine-wave shape. It is caused by the slots, the shape of the pole pieces, and the pulsation of the armature reaction. The third and the fifth harmonics, *i.e.*, with a frequency three and five times the fundamental, are generally the predominating in three-phase machines. The objection to higher harmonics is, among other things, their effect in increasing the maximum value of the electromotive force and the correspondingly increased insulation strain.

HARMONIC MOTION CURVE. The crank or harmonic motion curve works much more easily than the uniform curve, and a cam laid out with this motion may be run at a high speed without much shock or noise. To draw a diagram of this curve, draw a semi-circle having a diameter equal to the



Crank or Harmonic Motion Curve

stroke of the cam, and divide this semi-circle and the line representing the angle of motion into the same number of equal parts. The intersection of lines drawn from these divisions will give points on the curve. The illustration shows the harmonic curve and the manner in which it is obtained.

HARRISON CELL. This is a primary cell or battery having a zinc anode, a lead cathode, an electrolyte composed of pure dilute sulphuric acid or bisulphate of sodium or potassium, with lead peroxide as a depolarizer. It is used for closed circuits, and has an electromotive force of 2.5 volts.

HART'S INDIA-RUBBER CEMENT. This is an elastic cementing material made by heating together equal parts of raw linseed oil and pure masticated rubber, this mixture being made into a stiff putty with fine "paper stock" asbestos. The rubber may also first be dissolved in carbon disulphide, and then mixed with the linseed oil.

HARVEY GRIP THREAD. The characteristic feature of this thread is that one side inclines 44 degrees from a line at right angles to the axis, whereas the other side has an inclination of only 1 degree. This form of thread is sometimes used when there is considerable resistance or pressure in an axial direction and when it is desirable to reduce the radial or bursting pressure on the nut as much as possible.

HARVEY PROCESS. In 1891, H. A. Harvey invented a process for making solid steel armor plates. The essential principle of the Harvey process is the subjection of the plates, while they are in contact with finely divided charcoal, to a high temperature for about two weeks. They are then allowed to cool slowly to a dull red heat, and sprayed with water. Plates made by this process have about twice the resisting power of wrought iron. In principle, this is simply a casehardening process applied to unusually large objects: the carbon from the charcoal penetrates the surface of the metal and converts it into high-carbon steel. The depth of the penetration and the amount of the carbon absorbed by the surface of the armor plate increases with the temperature and with the length of time allowed for the process.

HAULAGE ROPE. Wire ropes made from six strands of seven wires each are known as "haulage" rope, and also as "transmission" or "standing" rope. This type of rope is not very flexible, and is generally made with large wires, in order to enable it to resist a great deal of external wear. It is used when the abrasive action is great but when the rope is not required to bend over many sheaves and when the diameter of the sheaves is comparatively large. A greater factor of safety is required in haulage rope than in more flexible rope.

HAYDEN CELL. This is a primary cell or battery similar to the Leclanché cell, except that the porous cup of the Leclanché cell in which the carbon cathode is placed is not used. The depolarizer is contained within a carbon cylinder. This is surrounded by a zinc cylinder which is held at the proper distance from the carbon cylinder by heavy rubber bands.

HEADER. A header is a large pipe into which one set of boilers is connected by suitable nozzles or tees, or similar large pipes from which a number of smaller ones lead to consuming points. Headers are often used for other purposes — for heaters or in refrigeration work. Headers are essentially branch pipes with many outlets, which are usually parallel. They are largely used for the tubes of water-tube boilers.

HEADING MACHINE. A machine for cold-heading rivets, screw blanks, etc. is called a heading machine or cold-header.

HEAD OR PRESSURE. The pressure against which a pump forces the water is usually expressed in "feet head." For example, a pump feeding a boiler against a pressure of 100 pounds per square inch is operating under a head of $100 \div 0.433 = 231$ feet; that is, each pound pressure per square inch against which the water is forced is equivalent to lifting a column of water 1 inch square and 2.31 feet high. From the above, it is evident that: Pressure per square inch in pounds $\div 0.433 =$ head in feet; and head in feet $\times 0.433 =$ pressure per square inch in pounds.

In determining the pressure head or total height to which the water must be raised, the distance must be taken from the surface of the water in the reservoir from which it is drawn to the point of discharge. The same power is required to raise water by suction as to force it, and the height of the pump above the water does not enter separately into the calculation at all. This is made plain by a practical example. Assume that a pump is raising water by "suction" 18 feet, and discharging it at this elevation without forcing it at all, all the work being done on the suction side of the piston. When water is raised to this height by suction, the air pressure in the suction pipe is reduced to $14.7 - (18 \times 0.433) = 6.9$ pounds per square inch. This leaves an unbalanced pressure upon the other side of the piston equal to $14.7 - 6.9 = 7.8$ pounds per square inch. The effect is, therefore, the same as if the pump were forcing the water against this pressure with the water flowing into the cylinder by gravity. To illustrate, take a case where the water flows to the pump by gravity, and is raised to a height of 18 feet. Here the pressure per square inch against which the piston must work is $18 \times 0.433 = 7.8$ pounds, the same as in the preceding case. Hence it is evident that the work done by the pump is the same whether the water is raised a given distance by suction or forced to the same height by the pressure of the piston.

Friction Head. — In what has been said regarding the pressure head required for raising water to a given height, or forcing it against a pressure, as in boiler feeding, no reference has been made to the resistance due to the friction of the water against the sides of the pipes. In computing the required power for operating a pump, and the pipe sizes in a boiler plant where the distances are short, no account is taken of this, but when water is moved long distances through pipes, the friction must be taken into consideration. For convenience in making computations, tables have been prepared giving the frictional resistance for pipes of different diameters and different velocities of flow of water.

HEADSTOCK. That part of a lathe and of certain other machine tools, which contains the main spindle with its driving mechanism, is known as the headstock. Some designs of engine lathes have what is commonly referred to as a *friction head.* This is simply a headstock arranged with a friction clutch between the cone-pulley and the large faceplate gear. This

clutch serves to connect either the cone-pulley and spindle for the direct drive, or the faceplate gear and spindle when the drive is through back gearing. The clutch is operated by a lever at the front of the headstock. This is a very convenient feature and makes it possible to change to the back-gear drive without stopping the lathe, and enables speed changes to be made much more quickly than with the ordinary design of headstock. Lathes which are commonly referred to by manufacturers as the *geared-head* type, have a headstock which contains a system of gearing so arranged that the drive may be transmitted through different combinations of gearing for varying the spindle speeds. There is a single belt pulley instead of a cone-pulley, and the gearing required for obtaining the necessary range of spindle speeds is entirely enclosed. The levers for controlling the clutches by means of which the speeds are varied are located in front of the headstock. The relative positions of the levers for obtaining a given speed are indicated by an index plate.

HEADSTOCK INVENTION. Richard Roberts, a Welshman and one of the first planer builders, invented the back-geared headstock for lathes about 1818. This headstock design, so far as the arrangement of the cone pulley and back gearing is concerned, is similar to present-day designs of the cone-pulley type. The cone-pulley could be disengaged so as to run free on the main spindle, and then the drive was from the cone pinion to the large back-gear and through the pinion on the back-gear shaft to the large gear on the main spindle, as on modern lathes.

"HEAT-BLACK" FINISH. The so-called "heat-black" finish on brass, copper, or bronze is adapted for a large variety of work. The article to be treated should be free from grease, although a slight tarnish will not affect it. Two stock solutions are first made up. One is a solution of nitrate of copper in water and the other is a solution of nitrate of silver in water. The *nitrate of copper* solution is composed of water, 1 ounce and nitrate of copper, 1 ounce. The *nitrate of silver* solution contains water, 1 ounce and nitrate of silver, 1 ounce. The mixed solution for applying to the metal is made as follows: water, 3 parts; nitrate of copper solution, 2 parts; nitrate of silver solution, 1 part. The solution is kept in a glass or stoneware vessel for use.

The parts to be treated, freed from grease, are heated over a bright charcoal fire, or by means of a gas torch, under a hood, by the side of the tank containing the solution. The solution is kept in a china or stone basin of suitable proportions for the work to be treated; such basin is covered with a wooden cover, and kept under the hood connected with the chimney drawing out the fumes generated, when the parts are dipped in the solution. After the parts have been dipped, they are allowed to drain over the basin

for a few seconds, and then heated again until the green froth is burnt and black. If the charcoal fire is used, care must be taken that the wet parts do not touch the coals, as this would cause discolored spots at every point of contact. It will not be detrimental to have the parts laying on the fire when they are dry and green all over. The brushing is made over a tank full of water by means of a wet brush to prevent inhaling the irritating dust. The parts are allowed to dry and afterwards may be finished or they may be smeared with oil, dried in sawdust, and brushed again, or else polished with black lead.

One or two coatings of the solution on the surface of the article is usually enough; it dries almost immediately leaving a green froth. The temperature is not sufficiently high to draw the temper of hard brass, but it will usually melt soft solder. When the entire surface has changed to a uniform black color, allow the article to cool and then brush off the fluffy material on the surface of the metal with a stiff-bristled brush. The color will now change to a brownish-black that is quite pleasing for many purposes.

When the smut has been brushed off from the surface of the article, it is immersed in a cold liver of sulphur solution for 5 minutes. This solution is made by dissolving 2 ounces of liver of sulphur in 1 gallon of water. The article is immersed in it, allowed to remain about 5 minutes and then, without rinsing, is again heated until the surface is uniformly black. The surface is now brushed again with the bristle brush when it will be found that the color is a dead black and quite uniform. If the article is lacquered with a flat lacquer or waxed, as may be desired, the final appearance of the surface will be found satisfactory. This is one of the most satisfactory black finishes known, as it is dead black, is readily applied, and very durable.

HEAT COLORING. Heat coloring is a method of producing a variety of colors on iron and steel articles by heating them until the desired shade is obtained, and then permitting them to cool off. One method is to heat a flat piece of iron and steel of sufficient size to retain the heat for some time and place the piece to be colored on the hot surface. When the desired color appears, the piece to be colored is plunged into an oil bath. Hot sand or a Bunsen burner may also be used for heat coloring.

HEAT DENSITY. The number of British thermal units (B.T.U.) of heat that are in a cubic foot of space under various conditions will be given approximately, assuming 0 degrees F. as a base. On a hot summer day, with the thermometer registering 110 degrees, there is only 1.8 B.T.U. to the cubic foot.

The gasoline blast torch is generally assumed to have a very hot flame, but in the hottest part of that flame the heat density is only 10 B.T.U. per cubic foot. Hydrogen gas, with its enormous heat value, might be expected to

have a larger number of units, but in the hottest part of a hydrogen flame burned in the air the B.T.U per cubic foot are just about 10.1; it has a heat density 1 per cent better than the gasoline flame in air. Carbon burned in air shows a density of 12.3 B.T.U. per cubic foot. Acetylene gas burned in air produces a heat density of 13.1 B.T.U. per cubic foot. Eliminate nitrogen and burn acetylene in oxygen and there are 24 B.T.U. in every cubic foot of the intense flame. Burn hydrogen in oxygen and there are 20 B.T.U. to the cubic foot.

Ordinary steam just as it boils off water into the atmosphere contains 44 B.T.U. to the cubic foot. The oxy-acetylene flame takes a poor second place when compared with steam under these conditions. Superheated steam at 240 pounds per square inch and 300 degrees of superheat, contains over 500 B.T.U. per cubic foot. Strange as it may seem, saturated high-pressure steam at 235 pounds per square inch contains over 650 B.T.U. per cubic foot, and for carrying heat is superior in this respect to superheated steam. A cake of ice at 32 degrees will deliver 937 B.T.U. per cubic foot when cooled down to zero. Boiling water holds over 12,000 B.T.U. per cubic foot.

Melted sulphur, at 800 degrees F., has a heat density about twice that of boiling water, or over 22,000 B.T.U. to the cubic foot. Melted aluminum, at 1214 degrees F., almost doubles this with nearly 43,000 B.T.U. per cubic foot. Melted glass, at 2377 degrees F., has nearly 75,000 B.T.U. in every cubic foot. Platinum, at 3300 degrees F., makes a big jump with its 182,200 B.T.U. per cubic foot. But common melted iron, at 2700 degrees F., leaves platinum away behind with 207,000 B.T.U. per cubic foot. However, they are all surpassed if a cubic foot of carbon is heated almost to its vaporizing temperature, say to 7000 degrees F., as a heat density of 700,000 B.T.U. per cubic foot is then obtained. It is impossible for a person to look at this heated carbon or stand near it, and probably it represents the greatest heat density known. It is found in every arc lamp.

HEAT EQUIVALENT OF WORK. It has been found by experiment that there is a definite relation between heat and work, in the ratio of one British thermal unit to 778 foot-pounds of work. The number 778 is commonly called the *heat equivalent of work* or the *mechanical equivalent of heat.*

A horsepower-hour equals $33{,}000 \times 60 = 1{,}980{,}000$ foot-pounds. The changing of one pound of water at 212 degrees F. into steam at that temperature, will require about 966 British thermal units, or $966 \times 778 = 751{,}600$ foot-pounds nearly. This being the case, it is evident that the number of pounds of water evaporated at 212 degrees F., which represent one horsepower-hour, equals $1{,}980{,}000 \div 751{,}600 = 2.64$ pounds of water.

HEATING SURFACE OF BOILERS. The heating surface of a boiler is that portion of the boiler which has one side of the plates or tubes exposed

to the hot gases of combustion and the other in contact with the water. In the case of horizontal tubular boilers of the fire-tube type, it is customary to assume that the heating surface is equal to the sum of one-half the shell, two-thirds the rear head less the tube area, and the interior surface of all the tubes.

HEAT INSULATING MATERIALS. See Insulation, Heat; also Pipe Coverings.

HEAT OF EVAPORATION. The heat of evaporation is the total amount of heat required for the changing of water of a given temperature into steam of the same temperature.

HEAT PUMP. The " heat pump " is an apparatus working on a reversed heat-engine cycle, the object of which is to economize heat in evaporating processes, such as the concentration or the distillation of liquids. In the heat-pump process the vapor from the evaporator is taken to a compressor, in which its pressure, and hence also its temperature, are raised to such a degree that the compressed vapor may serve as the heating medium in the evaporator. It is returned to the heating element of the evaporator accordingly, where it is used for the evaporation of a further amount of liquid. While in certain circumstances a small quantity of live steam may have to be supplied, in general the only energy required in order to carry on the process is that necessary to drive the compressor. The efficiency of the process from the thermal or energy point of view may therefore be measured by comparing the evaporative effect produced with the power expended in driving the compressor. This power may be derived from fuel consumed in the power unit or station from which the compressor is driven, or, of course, from any other source of power, such as water power, and involve no expenditure of fuel at all. Also the compressor may be driven directly by the prime mover or the drive may be indirect, the transmission being effected electrically. The compressor may also take the form of a jet pump supplied from an external source with steam which mixes with the vapor from the evaporator, and is delivered with it to the heating element. The variations of the process are numerous, but all are characterized by the fact that the vapor produced is compressed and returned to the evaporator as the heating medium.

HEAT RADIATION. See Radiation of Heat.

HEAT-RESISTING ALLOY. See Calite.

HEAT, SPECIFIC. See Specific Heat.

HEAT-TREATMENT. This term as applied to steel means, according to the S.A.E. definition, an operation or a combination of operations involving the heating and cooling of a metal or an alloy which is in the solid state, for

the purpose of obtaining certain desirable conditions or properties. Heating and cooling for the sole purpose of mechanical working is not classified as heat-treatment. Generally speaking, the heat-treatment of steel, includes hardening and tempering of high-carbon steels, casehardening of low-carbon steels, and annealing of steel. Refer to following sections and also to process or equipment, as, for example, Annealing; Barium-chloride Heating Baths; Casehardening Steel; Carburizing by Rotary Method; Cyanide Hardening; Hardening Steel; Local Hardening; Pack Hardening; Quenching Baths; Tempering.

HEAT-TREATMENT OF CARBON STEEL. The following recommendations of the American Society for Steel Treating cover the recommended practice adopted by the society for heat-treating plain carbon tool steel. The operations required for heat-treating or hardening plain carbon tool steel are heating, quenching, and tempering. The heating should be done uniformly to the temperature indicated in Table 1. From this temperature the steel is quenched in water, but should not be permitted to cool down below the temperature of boiling water (212 degrees F.). The steel may be tempered by being reheated immediately in oil, a salt bath ($NaNO_3$), or in a furnace. Tempering temperatures are given in Table 2.

Table 1. Hardening Carbon Tool Steel

Per Cent Carbon	Hardening Temperature, Degrees F.	Quenching Medium	Temperature of Quenching Medium, Degrees F.
0.65 to 0.80	1550 to 1450	Water	70
0.81 to 0.95	1460 to 1410	Water	70
0.96 to 1.10	1390 to 1430	Water	70
1.11 to 1.25	1380 to 1420	Water	70

Table 2. Tempering Carbon Tool Steel

Results Desired	Tempering Medium	Temperature, Degrees F.
Relieving strains	Oil	350 to 375
Relieving strains and reducing brittleness	Oil	400 to 500
Relieving strains and toughening	Oil	500 to 600

The quenching temperatures given are at the lowest temperature ranges consistent with the highest quality tools; deviations are not recommended, but may be necessary in unusual cases. Water is the common quenching medium, and by varying its temperature and manner of application for the abstraction of heat, almost any degree of variation of structural conditions of the tool steel can be obtained. There are, however, special cases where oil may be a more suitable quenching medium; judgment and experience are the only guides in cases of this kind.

The recommended practice for the heat-treatment of tool steel applies to the highest quality performance of tools for general purposes only. For specific applications, where special requirements seem to be necessary, deviation from the recommended practice must be left to the judgment of the individual heat-treater or metallurgist.

HEAT-TREATMENT OF HIGH-SPEED STEEL. The following directions are recommended by the American Society for Heat-treating and apply in the heat-treatment of 18 per cent tungsten high-speed steel:

Annealing. — Heat slowly and uniformly to a temperature of 1600 degrees F., and hold at that temperature to obtain uniformity of internal condition and grain. Cool in a furnace or in infusorial earth, mica, lime, or any medium that will permit slow, uniform cooling. Cooling in air should not be permitted, since air cooling from the annealing temperature is likely to result in partial hardening of the tool.

Preheating for Hardening. — Heat slowly and uniformly to 1500 degrees F. in a furnace of sufficient size. It is the customary practice always to preheat for hardening in an open furnace, since preheating in a salt bath causes the salt to adhere to the tool, and the subsequent high temperature treatment causes unusual corroding from the adhering salt. Even preheating in lead is objectionable from small quantities of adhering lead. There is not much advantage to be gained in using a molten bath for the preheating, since the preheating temperature may vary over the comparatively wide range of 1400 to 1600 degrees F., and an open furnace is invariably used in practice.

Heating for Quenching. — Transfer the preheated steel to a high-temperature furnace which is maintained at a temperature of from 2250 to 2400 degrees F., depending upon the type of tools being hardened. In order to obtain the most satisfactory "red hardness" conditions, the steel should be brought rapidly to the higher temperature; but in many cases the character of the cutting edges of certain form tools, such as milling cutters, threading tools, etc., makes it inadvisable to use the higher temperatures because of the danger of destroying the delicate edges through blistering, pitting, etc. It is therefore usual to employ the higher temperatures for such tools as rough lathe tools, while the finer class of tools is hardened at the lower

temperatures. High-speed steel tools should not be held at the high heat longer than necessary, since holding at the high hardening temperatures causes excessive grain growth, with subsequent brittleness of the hardened tools. Tools that cannot be ground after hardening are often heated in a barium chloride or some similar salt bath.

Quenching. — Quench the steel in oil or air from the hardening temperature. It is advisable to maintain the oil quenching bath at a temperature of 150 to 200 degrees F. to eliminate possibility of breakage with intricately shaped tools.

Tempering for Secondary Hardness. — Reheat the steel uniformly in an open furnace or in a lead bath, or preferably in a sodium nitrate ($NaNO_3$) bath, or in any other suitable salt bath, to a temperature of from 1050 to 1150 degrees F. for a sufficient length of time, and cool in air. Quenching from the tempering temperatures is not advisable with high-speed steel.

HEAT UNITS. The unit of heat measurement used in English-speaking countries is the British thermal unit (B.T.U.), which is the quantity of heat required to raise the temperature of one pound of pure water one degree F. The French thermal unit, or kilogram-calorie, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C. One kilogram-calorie equals 3.968 British thermal units, and it also equals 1000 gram-calories. The number of foot-pounds of mechanical energy equivalent to one British thermal unit is called the "mechanical equivalent of heat," and equals 778 foot-pounds. One foot-pound equals 0.001285 heat unit.

HECTOGRAPH COMPOSITION. This is a compound used as an oil-proof cement, consisting of two parts of good glue or gelatin, one part of glycerin, and seven parts of water, the preparation being applied warm. On cooling it will stiffen quickly.

HEFNER STANDARD. The Hefner standard or unit is the standard of intensity of light as adopted in Germany. The standard intensity of a Hefner is equal to 0.9 international candle, the latter having, since 1909, been established as the national standard for light intensity in Great Britain, France, and the United States. The Hefner standard is the light produced by a wick lamp burning amyl acetate of definitely specific chemical and physical properties, the standard height of flame being 40 millimeters (about $1\frac{5}{8}$ inch). The Hefner standard as a unit for the intensity of light is objected to on account of its low intensity, its reddish color, and its sensitiveness to variations in the height of the flame. The element of uncertainty is estimated to almost always exceed 2 per cent.

HELE-SHAW CLUTCH. This is a clutch devised by Prof. Hele-Shaw. Its principal feature is that power is transmitted through the friction be-

tween grooved disks. A number of these disks are placed in the clutch, each disk having a V-groove which fits into the V-groove of the next disk. Every other disk is connected to an outside drum, and the alternating disks, to the shaft to which power is to be transmitted. It has been found that V-shaped disks transmit considerably more power and permit of a more even " pick-up " than clutches with flat disks.

HELICAL. See Helix Angle; also Spiral and Helix.

HELICAL GEARS. Gears which have a cylindrical pitch surface and teeth which coincide with helical curves on the surface of the pitch cylinder, are known as *helical gears*. In common usage, they are also termed " spiral " gears, although this latter term is theoretically incorrect.

Helical gears for parallel shaft drives have several inherent advantages as compared with the spur type. First, the action is distributed over more than one tooth, and all phases of tooth engagement, such as sliding and rolling contact, occur simultaneously, which tends to equalize wear and preserve the correct tooth shape. The load is transferred gradually and uniformly as successive teeth come into engagement, and the bending action resulting from the tooth load is less than for a spur gear, because the line of contact extends diagonally across the meshing teeth; the tooth load of a helical gear, however, is higher because of the angular position of the teeth, and the normal tooth section is, of course, smaller than that of a spur gear of the same circular pitch. Helical gearing for driving shafts which are not intersecting and not parallel is generally considered a rather treacherous type to use, when the amount of power is relatively high. In most installations, the power transmitted is much less than the maximum capacity of the gearing, and whenever the amount of power is likely to be anywhere near the maximum, it is preferable to use worm-gearing, the worm having as many threads as are required to give the desired velocity ratio. Helical gears that have caused trouble due to abrasion resulting from the small contact area and highly localized pressure, have often been replaced by worm-gearing with satisfactory results. Whenever there is any doubt about the power-transmitting capacity of helical gearing, it is not advisable to rely upon calculations, but to determine this capacity by an actual test under actual running conditions, as regards speed, lubrication, and load. See also Herringbone Gears.

HELICAL GEARS, CUTTING. Helical gearing is usually cut by some generating method although milling machines are sometimes used, especially when such gears are not required in quantity. Large helical gears, particularly in the herringbone form, may also be cut on planers of the form-copying type and by the end-milling process. The most common generating method employed is that of hobbing. Gear hobbing machines are very

efficient for cutting helical gears, and are widely used for this class of work as well as for spur gears. The general method for cutting helical gears by hobbing is practically the same as cutting spur gears, after the machine is properly geared and adjusted.

Shaping or planing processes of cutting helical gears are used in many shops. The cutter used on a Fellows helical gear shaper resembles a helical gear and has a rotary movement in unison with the gear blank being cut, the principle of operation being similar to that of the shaper for spur gears.

HELICAL GEARS, END THRUST. In order to determine the end thrust of helical gearing, first calculate the tangential load on the gear teeth. If the amount of power to be transmitted is 7 horsepower and the pitch-line velocity 200 feet per minute, the tangential load will equal $33,000 \times 7 \div 200 = 1155$ pounds. The axial or end thrust may now be determined approximately by multiplying the tangential load by the tangent of the tooth angle. Thus, in this instance, the thrust $= 1155 \times \tan 15$ degrees $=$ about 310 pounds. The end thrust obtained by this calculation will be somewhat greater than the actual end thrust, because frictional losses in the shaft bearings, etc., have not been taken into account, although a test on a helical gear set, with a motor drive, showed that the actual thrust of the $7\frac{1}{2}$-degree helical gears tested, was not much below the theoretical values.

The ratio between peripheral tooth pressure and resultant thrust was determined by measurements taken while the gearing was in operation under various loads. The tangential tooth pressure was determined in the usual way from observed revolutions per minute and wattage. Corrections of horsepower were made from an efficiency chart of the motor. The thrust was measured by applying a graduated spring balance against the end of the motor shaft with sufficient pressure to balance the thrust and move the shaft away from the face of the bearing. As there was over $\frac{1}{4}$ inch end play between the bearings, it was easy to tell when the thrust surfaces were separated. This test brought out conclusively that the thrust developed by helical gearing was practically proportional to the tangent of the helical angle.

HELICAL GEARS, SINGLE. Single helical or "twisted spur gears" are used on parallel shaft drives to obtain smoother action than is obtained with ordinary spur gears. In designing gears of this type, the aim is to incline the teeth sufficiently to secure smooth action without excessive end thrust. The angle should be such that one end of a tooth remains in contact until the opposite end of the following tooth has come into engagement. The angle required to obtain this overlapping depends upon the face width of the gear, decreasing as the face width increases.

According to most text-books, the maximum angle for single helical gears

should be about 20 degrees, although one prominent manufacturer mentions that the maximum angle for industrial drives ordinarily does not exceed 10 degrees, and this will give quiet running without excessive end thrust. On some of the heavier single helical gearing used for street railway transmissions, etc., an angle of 7 degrees is employed. It will be understood that this is the helix angle between the tooth and the axis of the gear.

The selection of an angle may depend to some extent upon the allowable end thrust, as, for example, in cases where a certain amount of end thrust would be tolerated in order to use a larger angle and obtain smoother tooth action.

HELICOPTER. The helicopter differs from the airplane in that it obtains its lift directly from the propellers and not through a component of resistance of the air acting on planes inclined at an angle to the direction of the motion of the machine. The helicopter idea is at least as old as, if not older than, that of the airplane, but, up to the present, little progress has been made in the development of a practical machine.

HELIUM. Helium is one of the lightest of the gases, although not so light as hydrogen, its specific gravity, compared with air as a unit, being 0.138. Helium is present in small quantities in the atmosphere, and also in many minerals. It is contained almost universally in the gases in the water of thermal springs. It does not enter into a chemical combination with any other chemical element, but is always mechanically mixed or contained in the substance in which it is found. Helium becomes liquid at a temperature of only a few degrees above the absolute zero, and becomes solid at a temperature only two degrees below that at which it liquefies, these temperatures being around −267 degrees C. (−449 degrees F.). According to laboratory experiments at the University of Leyden, Holland, it appears that at absolute zero a pressure of about 16 atmospheres would be required to solidify helium. The actual solidification took place at a temperature about 2.2 degrees C. above absolute zero at a pressure of 50 atmospheres, and at 4.2 degrees C. above absolute zero at a pressure of 140 atmospheres. Solid helium forms a homogeneous transparent mass which differs to an extremely small extent from the appearance of liquid helium.

HELIX. A helix is a curve in three dimensions; that is, it is not a curve situated in one plane. Examples of this curve are found in the helical spring, the helical or spiral gear, and the ordinary screw thread. In a sharp V screw thread, for example, the line forming the top of the thread forms a helix. The distance between the various convolutions of the helix, measured parallel to its axis, is known as its *lead*. Helices are often, although incorrectly, referred to as *spirals*. A spiral, however, is a curve situated in one plane

and is exemplified by an ordinary watch spring having consecutive layers or convolutions extending outward.

HELIX ANGLE. If the base of a right-angle triangle equals the lead of a screw thread and if the altitude equals the pitch circumference of the screw, then the angle between the hypotenuse and altitude of the triangle equals the helix angle of that screw thread at the pitch line; hence, the tangent of the helix angle equals the lead of the thread divided by the pitch circumference (circumference at one-half the thread depth). It is evident from the foregoing that the helix angle of a screw thread is measured from a plane perpendicular to the screw axis. If the helix angle at the top of a screw thread were required, the circumference at the outside diameter would be taken instead of the pitch circumference.

The helix angle of a helical (spiral) gear is measured from the axis. Thus if the lead (axial distance that a tooth would advance if it made one complete turn) of a helical gear equals the base of a right-angle triangle and if the pitch circumference of the gear equals the altitude, then the angle between the hypotenuse and the base equals the helix angle; hence, the tangent of this helix angle equals the pitch circumference of the gear divided by the lead of the helix.

HELVE HAMMERS. The power hammer commonly known as a *helve* hammer, is so named because the upper hammer die is attached to the end of a wooden helve. The hammer of a typical design is driven by a belt operating on a pulley and on the shaft which carries this pulley, there is an eccentric which, by means of a suitable strap and connecting-rod, operates a lever or arm which, in turn, actuates the hammer helve; motion is imparted to the helve through rubber cushions which impart " snap " and elasticity to the blow. The wooden helve is hung upon hardened steel centers and may be adjusted to accommodate variations either in the thickness of the die or of the stock that is to be forged. The hammer is controlled by a foot-treadle which extends around the side and front of the hammer base. Helve hammers are made in several different designs which differ either in regard to the method of imparting motion to the helve or in the arrangement of the hammer die. Hammers of the helve class are especially adapted for comparatively light forging operations which require a succession of rapid blows, and they are extensively used for drawing out stock and, in some cases, special dies are employed for producing duplicate forgings of uniform shape and size.

HEMATITE ORE. Hematite ore, also frequently known as " red hematite," is an iron oxide of the composition Fe_2O_3, containing about 70 per cent of iron. Approximately, 93 per cent of the iron ores mined in the

United States belong to this class. The color of hematite varies from a bluish gray to a deep red, but it always gives a red streak on a porcelain plate. The hardness of hematite varies from 5.5 to 6.5 on the Mohs scale. The specific gravity varies from 4.2 to 5.3. Hematite is an anhydrous oxide containing no water in combination after having been heated to a temperature of 212 degrees F. See Iron in Iron Ore; also Magnetite.

HEMP ROPE. The fiber of the hemp plant is used for making hemp rope. Hemp rope is not so strong as Manila rope of the same size. A hemp rope, if dry and untarred, will break from its own weight, at a length of about 2800 feet. If wet and tarred, it will break from its own weight at about 2000 feet. Sometimes, when the depths at which ropes are used are very great, they are given approximately the form of a body of uniform strength, by making them of separate pieces, the diameters of which diminish toward the lower end. In this way, the stresses in the fibers due to the rope's own weight can be considerably decreased.

HENRY. The unit of inductance is called the *henry,* which is the inductance of a coil in which a current varying at the rate of one ampere per second will induce one volt. The one volt induced does not include the electromotive force necessary to overcome the resistance of the circuit. As this unit is too large for practical purposes, the *millihenry* (one thousandth of a henry) is the unit used in rating coils and electromagnets.

HEPTAGON. Any plane figure or surface bounded by seven straight lines is called a *heptagon.* If all of the sides are of equal length and the angles between the sides are equal, the figure is called a *regular* heptagon.

HERCULES CELL. This is a primary cell or battery using a zinc anode and a carbon cathode, with a solution of ammonium chloride (NH_4Cl) as an electrolyte. No depolarizer is used. The cell is employed for open circuits and has an electromotive force of from 1.3 to 4 volts.

HERMAPHRODITE CALIPER. A caliper provided with one straight pointed leg similar to that of a divider, and one leg with a bent end similar to that of an ordinary machinist's inside caliper is known as a hermaphrodite caliper. Calipers of this type are used in laying off distances from the edge of a piece of work and for locating the center of round work.

HERRINGBONE GEARS. When helical gears transmit motion between two parallel shafts, end-thrust may be avoided by using right- and left-hand helical gears side by side. This type of gearing has been termed "herringbone" gearing. With herringbone gearing all phases of engagement take place simultaneously. This holds good for every position of pinion and gear, provided that the relationship between pitch, face width,

and helix angle is such as will insure a complete overlap of engagement. Since all phases of engagement occur together, it follows that the load is partly carried by tooth surfaces in sliding contact and partly by surfaces in rolling contact. The result is that portions of the teeth farthest from the pitch-line, which engage with sliding action, tend to wear away more rapidly than the portions nearest the pitch-line; but the pitch-line portion is always carrying part of the load, and the effect of wear on the ends of the teeth merely tends to throw more load on the center portions; in other words, there is a tendency to concentrate the load near the pitch-lines. The minute extra wear that does take place at the ends is only the amount necessary to transfer a certain proportion of the load near the pitch-lines, so that the wear is equalized all over the surface of the teeth, those portions in sliding contact carrying less than those in rolling contact.

As the teeth keep their involute form, motion is transmitted from the pinion to the gear in an even manner, without jar, shock, or vibration. Although herringbone teeth may not be intrinsically stronger than straight teeth, the elimination of shock renders them capable of transmitting heavier loads. Since all phases of engagement occur simultaneously, the transference of the load from one pinion tooth to the next takes place gradually instead of suddenly. In straight gears, the continuity of action is a function of the number of teeth in the pinion. In herringbone gears continuity depends upon the relationship between the face width and the number of teeth in the pinion. With herringbone gearing the bending stress on the teeth does not fluctuate from maximum to minimum, as in straight gears, but remains always near the mean value. This feature is of especial importance in rolling-mill driving and work of a similar nature. Herringbone gears are especially applicable for high velocities and ratios in connection with turbine reduction gearing or for installations requiring a minimum of vibration and noise. Accurate and well-made herringbone gears are often operated at pitch-line velocities of from 3000 to 5000 feet per minute in connection with steam turbine reduction gearing, and the ratios may be 10 to 1 or higher for some installations.

Double helical or herringbone gears may be produced either by hobbing, planing (using either a gear shaper or planer) or milling. In hobbing gears of this type, an ordinary machine designed for cutting spur and helical gears may be used, or the work may be done on a special machine intended particularly for herringbone gears. If the planing process is employed, the teeth may be formed by a generating method, or a machine of the templet or form-copying type may be used.

Wuest Herringbone Gears. — The teeth of the Wuest gears are so designed that those on the right- and left-hand sides of the gears are stepped half a space apart and do not meet at a common apex at the center of the face,

as in the usual type of herringbone gear. The stepped form will wear more evenly under extreme loads than the ordinary type.

HEXAVALENT. This term is used to indicate that an atom of one element will combine with six atoms of another element. It is also known as sexivalent.

HIGH BRASS. What is known as "high brass" is especially suitable for cold rolling and drawing; it contains from 30 to 40 per cent of zinc, the remainder being copper. If there is over 0.1 per cent of lead, the ductility of the brass is decreased and for this reason sheet brass intended for drawing purposes should be as free from lead as possible.

HIGH-SPEED STEEL. The expression "high-speed steel" is derived from the fact that such steel is capable of cutting metal at a much higher rate of speed than ordinary tool steels. The reason why it can be used at high speeds is that it has a special property known as "red hardness," or, in other words, this steel is able to retain its hardness even when heated to a temperature of dull red; hence, when cutting at a high rate of speed, the steel, although it becomes heated to a degree which would make an ordinary tool steel useless, retains its cutting qualities. A high-speed steel is not necessarily one conforming to any given analysis, nor is tungsten a necessary element. Most high-speed steels contain tungsten, but other elements, such as molybdenum, confer the red-hardness characteristic. A high-speed steel is one that cuts metals at a much higher rate of speed than ordinary carbon tool steel. A high-speed steel should continue to cut when the point of the tool becomes heated to a dull red temperature because of the red-hardness characteristic conferred upon it by tungsten, molybdenum or other alloys.

Why High-speed Steels Retain Hardness. — The effect of different elements entering into the composition of high-speed steels and the reasons why tungsten, manganese, chromium, and other elements give steels of this class such unusual properties will be more apparent by considering first the changes that occur in the hardening of ordinary carbon steel. The pearlite, ferrite, and cementite of annealed steels are replaced by other constituents when the steel is subjected to the heat-treatment required for hardening and tempering. Annealed steel containing approximately 0.90 per cent of carbon is composed entirely of pearlite. Incidentally, the composition of most of the steels of which cutting tools are made is largely pearlite before the steel is hardened. Steels that contain less than 0.90 per cent of carbon have, in addition to pearlite, ferrite, which increases as the carbon content decreases. If there is more than 0.90 per cent of carbon, the steel is composed of pearlite and cementite.

Now if any of these steels are heated sufficiently, the elements referred to

change to austenite. If the annealed steel has 0.90 per cent of carbon and is all pearlite, the change to austenite occurs at about 1355 degrees F., but the effect of either ferrite or cementite is to increase the temperature at which conversion to austenite occurs. After a steel has been heated sufficiently to change it to the austenitic condition, some of this austenite may remain after the steel has been cooled to the temperature of the atmosphere, although this necessitates very rapid cooling. Were it not for the carbon element, the austenite could not be retained even though the rate of cooling were extremely rapid, the effect of carbon being to obstruct the change and assist in keeping the steel in the austenitic condition. The carbon, therefore, acts as a fixing agent, and if there is a carbon content of over 1 per cent, the austenite may be fixed in cold steel, provided the steel is heated to a white heat and is then cooled very rapidly by using a quenching bath such as iced brine, which is below the freezing point of water.

The ordinary methods of heat-treatment produce martensite which is harder than austenite. Martensite is formed between the change from austenite to pearlite, the order being from austenite to martensite, as the steel cools. The change from austenite to martensite is difficult to prevent, because it occurs rapidly, the change from martensite to pearlite being relatively slow. While the hardness of martensite is a desirable quality, steel in this condition is too brittle for most purposes, and it is necessary to sacrifice the hardness by tempering, which toughens the steel and makes it better able to withstand shocks. The practical effect of tempering is to reduce the martensite or " let it down " toward the pearlite condition resulting in the formation of troostite (which occurs between martensite and pearlite) and of sorbite.

Influence of Tungsten. — Tungsten delays the change from austenite to pearlite. The effect is so pronounced that the change will be prevented entirely if there is 7 per cent or more of tungsten, even though the heated steel is allowed to cool slowly in the air. For this reason, it is necessary to cool a tungsten steel at an extremely slow rate in order to anneal it or to change it to the pearlite condition. The reason why high-speed steels in general can be heated considerably as the result of high cutting speeds and excessive friction is that some element (or combination of elements), such, for example, as tungsten, so changes the characteristics of the steel that the increase of temperature does not reduce it to the pearlitic stage, the same as with ordinary carbon steel. The martensite in carbon steel will not remain fixed if the steel is heated beyond a certain point, but if there is sufficient tungsten in the composition, the martensite remains even though the temperature is raised above that required for tempering. The natural tendency is for the martensite to change to troostite and finally back to pearlite, or to the condition normal to annealed steel. The effect of tungsten

to resist change from the martensitic condition explains why steel may have the property of red hardness. See Heat-treatment of High-speed Steel.

HIGH-SPEED STEEL, TUNGSTENLESS. See Cobaltcrom Steel.

HINDLEY WORM GEARING. Worm gearing of the Hindley type is generally supposed to have been originated by Henry Hindley, a noted clock-maker in York, England. There is no record of the year in which the Hindley worm gear was first made, but it was used in a dividing engine and described in a paper presented to the Royal Society by John Smeaton in 1785. In 1741 Smeaton had been shown a dividing engine containing this gearing. Hindley was also the inventor of the Hindley dividing engine, which was one of the first devices for accurately dividing a circle into a given number of equal parts.

Hindley worm-gearing or "globoid" gearing differs from ordinary worm-gearing in that the worm is curved in a lengthwise direction to fit the worm-gear, instead of being cylindrical. The idea is to so shape the worm that it will make contact throughout its length with the worm-gear, instead of engaging the gear along the mid-section only. Although perfect surface contact over all of the teeth in mesh is not obtained, the contact is doubtless of a superior nature in well-constructed Hindley gearing. The exact nature and extent of the contact, however, is uncertain, owing to the fact that the theoretical contact does not agree with the results actually obtained by commercial manufacturing methods, which alter to some extent the theoretical form.

HOBBING DIE IMPRESSIONS. This method is designated as hobbing or hubbing, because a "hob" or "hub" is used, which is in the form of a punch and has a shape corresponding to the impression required in the die. See Hub Method of Die-sinking.

HOBBING PROCESS. Gear teeth cut by the hobbing process are given the required shape or curvature by a generating action resulting from the rotation of the gear blank relative to a cutter of the hob form. Gear-hobbing machines are commonly applied to the cutting of spur, helical, and worm gearing, and hobbing is the most rapid method of cutting gears by a generating process. In the practical application of the generating principle to gear-hobbing machines, the hob used has cutting teeth of the same cross-sectional shape as teeth of a rack of corresponding pitch, except for minor variations such, for example, as increasing the length of the hob teeth to provide for clearance at the bottom of the tooth spaces. As the hob teeth lie along a helical path (like a screw thread) the hob is set at an angle to align the teeth on the cutting side with the axis of the gear blank. When the hob is inclined an amount depending upon the helix angle of its teeth, the latter, on the cutting side, represent a rack.

When a hobbing machine is in operation, the gear blank and hob revolve together, the ratio depending upon the number of teeth in the gear and the number of threads on the hob — that is, whether the hob has a single or a multiple thread. This rotation of the hob causes successive teeth to occupy positions corresponding to the teeth of a rack, assuming that the latter were in mesh with the revolving gear and moving tangentially. In conjunction with the rotary movement of the hob, the slide on which it is carried is given a feeding movement parallel to the axis of the gear blank. As this feeding movement continues across the gear blank (or blanks when several are cut together) all of the gear teeth are completely formed; thus hobbing is a continuous operation, since the teeth around the entire circumference of the gear are finished together (instead of one tooth being cut at a time) and ordinarily by one passage of the hob.

HOB " END ANGLE." The angle at which the hob-spindle or swivel slide is set depends upon the lead of the hob thread and its diameter, since the object of inclining the hob is to bring the teeth on the cutting side into alignment with the axis of the gear blank. This angle is equal to the helix angle of the hob thread at the pitch-line, measured from a plane perpendicular to the hob axis, and is often called the " end angle." To avoid the necessity of making calculations, this angle is usually stamped on the hob. If the angle is not known, its tangent may be determined simply by dividing the lead of the hob thread by the pitch circumference.

HOB FLUTES. If a hob is to be used in a gear-hobbing machine in which the hob and blank are positively geared together, the number of flutes may be comparatively small as compared with a hob that is to be used for hobbing worm-gears in a milling machine. A rule that agrees well with present practice is as follows: *To find the number of flutes in a hob, multiply the diameter of the hob by three, and divide by twice the circular pitch.* This rule gives approximate results on hobs for general purposes. In addition, the following considerations must be taken into account. Some authorities on worm gearing state that the number of flutes in a hob should in no case be an exact multiple of the number of threads. Their reason for this rule is that the hob so gashed will produce a much smoother tooth and one nearer correct in shape, because no tooth in the hob passes the same tooth in the gear twice in succession, so that any imperfections in the shape of the individual hob teeth are counteracted by one another. According to another authority, the circumferential distance from flute to flute should not be equal to or equally divisible by the circular pitch, for the same reason as stated regarding the former rule. From the foregoing statements, it is seen that to obtain a rule that would be at once simple and yet take all conditions into consideration, would be difficult.

It is important that the number of flutes or gashes in hobs bear a certain relation to the number of threads in the hob and the number of teeth in the worm-wheel to be hobbed. Avoid having a common factor between the number of threads in the hob and the number of flutes; that is, if the worm is double-threaded, the number of gashes should be, say, 7 or 9, rather than 8. If it is triple-threaded, the number of gashes should be 7 or 11, rather than 6 or 9. The second requirement is to avoid having a common factor between the number of threads in the hob and the number of teeth in the worm-wheel. For example, if the number of teeth in the wheel is 28, it would be best to have the hob triple-threaded, as 3 is not a factor of 28. Again, if there were to be 36 threads in the worm-gear, it would be preferable to have 5 threads in the hob. It is desirable that hobs should be fluted at right angles to the direction of the thread. Sometimes, however, it is necessary to modify this requirement to a slight degree, because the hobs cannot be relieved unless the number of teeth in one revolution, along the thread helix, is such that the relieving attachment can be properly geared to suit it.

HOB METHOD OF DIE-SINKING. See Hub Method of Die-sinking.

HOBS, MULTIPLE-THREADED. In cutting spur gears by the hobbing process, double- or even triple-threaded hobs are sometimes used instead of a single-threaded hob. A multiple-threaded hob will reduce the actual cutting time in direct proportion to the number of threads, as compared with a single-threaded hob of equal size, having the same speed and feed. A single-threaded hob, however, generates more accurate teeth, and it is the type commonly used. The reason that a hob having a double or triple thread reduces the cutting time in proportion to the number of threads will be evident by considering a specific example.

Assume that the gear to be hobbed has forty teeth, the hob feed per gear revolution is 0.1 inch, the total hob travel 2 inches, and the hob speed 100 revolutions per minute. In using a single-threaded hob, the gear will revolve 20 times while the teeth are being cut, since $2 \div 0.1 = 20$; hence, the hob makes $20 \times 40 = 800$ revolutions while traveling 2 inches, and as the hob speed is 100 revolutions per minute, the actual cutting time equals $800 \div 100 = 8$ minutes.

Assume now that the same gear is to be cut with a double-threaded hob. If the feed is still 0.1 inch per gear revolution, 20 gear revolutions will be required for a total hob travel of 2 inches as before. The hob, however, makes 20 revolutions to one of the gear, instead of 40, as with the single-threaded hob. Since the double-threaded hob also rotates 100 revolutions per minute, the gear will have a speed of $100 \div 20 = 5$ revolutions per minute, instead of $100 \div 40 = 2\frac{1}{2}$ revolutions per minute, as for a single-

threaded hob; consequently, if the double-threaded hob feed is $\frac{1}{10}$ inch per gear revolution, it moves $\frac{1}{10} \times 5 = \frac{5}{10}$ inch per minute, and it travels the required 2 inches in $2 \div 0.5 = 4$ minutes. This time, as will be seen, is one-half that required for a single-threaded hob, because the gear blank rotates at twice the speed when using a double-threaded hob.

If a similar comparison were made between a single-threaded and a triple-threaded hob, it would be found that the latter would require only one-third the cutting time needed for a single-threaded hob. The triple-threaded form is sometimes used for cast-iron gears which do not need to be very accurate. When multiple-threaded hobs are used for steel gears, ordinarily the double-threaded form is employed.

HOBS, TAPER. Hobs that are tapering on the leading end and that feed tangentially are especially adapted for cutting worm-gears of large helix angle. The use of a taper hob makes it possible to cut worm-gears more rapidly than with a fly-cutter, and also very accurately, provided the hob itself is accurate. The taper-hob method also increases the rate of production as compared with the use of straight hobs which are fed in radially. In the taper-hob method, the rotation of the hob relative to the blank, as the hob moves tangentially, is such as to advance or screw the hob slowly along its own thread. The action of the hob is the same as that of a fly cutter, and machines adapted for the fly-cutter method may also be equipped with taper hobs. The leading teeth on the hob are tapering, and they should be designed to increase progressively in width as well as in height from the small to the full-size end. The tapering or leading end performs a roughing operation, whereas the full-sized teeth take light finishing cuts, thus preserving their accuracy and insuring well formed teeth. The tangential feeding movement continues until the large end of the hob passes out of contact on the side opposite the starting point.

HOB TAPS. Hob taps are, as a rule, only intended for final finishing or sizing of the threads in dies. For this reason, their construction differs from that of ordinary hand taps. They are merely used for burring a thread already cut with ordinary taps. Straight hob taps are not relieved either on the top or in the angle of the parallel portion of the thread. Two or, at most, three threads, however, are chamfered at the point of the tap, and these chamfered threads are relieved on the top of the thread the same as ordinary hand taps.

HOEPFNER PROCESS. Two processes for the electrolytic production of metals are known as "Hoepfner" processes, from the inventor. The Hoepfner process for the electrolytic production of copper directly from its ore is briefly as follows: The copper ore, in the form of copper sulphide, is dissolved in a cupric-chloride solution also containing sodium chloride.

The cuprous chloride resulting from the reaction, which is insoluble in water, is held in solution by the sodium chloride. The anode and cathode of the electrolytic cell are separated by a diaphragm. Part of the copper is first deposited on the cathode, and then the solution circulates to the anode, where the cuprous chloride is oxidized to cupric chloride. The cycle is then repeated. In the Hoepfner zinc process, the zinc ore is first roasted, the zinc dissolved, and deposited by electrolysis, with insoluble anodes. Zinc, however, is not refined electrolytically to any large extent, because there is very little demand for zinc of the high purity obtained by electrolytic means. In the ordinary metallurgical processes, however, there is a large loss of zinc, and, for this reason, it is possible that, in the future, the electrolytic process may become more important than at present.

HOISTING ROPE. Hoisting rope is made from 6 strands of 19 wires each, and is used for elevators of all kinds, mines, conveyors, derricks, etc. The wires are smaller than those used in the 6 by 7 haulage rope and are, therefore, not as well suited to resist abrasive action, but the rope can be more easily bent over sheaves and drums. *Special flexible hoisting rope* consists of 6 strands with 37 wires each, and is used for cranes, counterweights, dredges, and similar purposes. It possesses greater flexibility than the ordinary hoisting rope and can be bent over smaller sheaves, but is not suitable for use where it would be exposed to a great deal of external wear, because the wires are of small size and rapidly wear off. *Extra-flexible hoisting rope* is made from 8 strands of 19 wires each, and is used for practically the same purposes as special flexible hoisting rope. It has about the same flexibility as this rope but is not as strong for a corresponding diameter, because it has a larger central hemp core.

HOISTS. The hoists used in machine shops and various classes of industrial plants, for lifting heavy parts, may be broadly classified as *hand-operated* and *power-operated* hoists. The common types of power-operated hoists are driven either by an electric motor or a pneumatic motor; with the so-called "air hoists," the load is lifted by the direct application of air pressure in a cylinder containing a piston that is attached to the lifting member of the hoist. The *differential hoist* or chain block, which was invented in 1854 by Thomas A. Weston, is based upon the principle of the Chinese windlass, an endless chain being substituted for the windlass rope and iron sheaves for the wooden drum. The chain hoist commonly known as the "screw" or "screw-geared" type, is so named because the power is transmitted from the hand chain to the load chain through a worm or screw which meshes with a worm-wheel. The spur-geared type of chain hoist is now used extensively and, if properly designed and built, is efficient.

Many *electric hoists* are equipped with motor-driven trolleys, some of

which are controlled from the floor by pendant cords, while others have an operator's cage. When an electric hoist is not attached to a trolley, it is usually provided with a hook so that it can readily be suspended from a crane, or wherever the hoist is needed. The hoist is controlled by pendant cords or chains from the floor, connected with a variable-speed controller which operates in conjunction with the brake.

The air-motor or pneumatic, geared type of hoist is equipped with some form of air motor which drives the lifting drum through suitable reduction gearing.

Air Hoists. — There are three general classes of *air hoists* of the cylinder type. With the *single-acting type*, compressed air is admitted to the lower or stuffing-box side of the piston only, and, when lowering the hoist, this air is exhausted. The *air-balanced type* of hoist is so arranged that there is full air pressure on the stuffing-box side of the piston at all times. The load is hoisted by exhausting air from the space above the piston, and is lowered by admitting air above the piston; the unbalanced area due to the space occupied by the piston-rod aids in forcing the piston downward. The advantage of this arrangement is accuracy of control. The *double-acting type* differs from the balanced type in that air may be admitted and exhausted from either side of the piston, so that the latter may be moved in either direction with equal power. Thus, with a balanced hoist, there is a constant pressure on one side of the piston and a variable pressure on the other, whereas, with a double-acting type, the pressure on either side of the piston may be varied in accordance with the amount of the load and the direction in which the force must be applied. For this reason, hoists of the double-acting type are used whenever either a pushing or pulling effect may be required.

HOLD-BACK DOG. See Dogs or Drivers.

HOLLOW-BLAST GRATE. This is a furnace grate designed especially for the burning of wood refuse, such as sawdust, bark, and chips, which cannot be easily burned on an ordinary form of grate. The grate consists of a series of hollow bars connected with a blast fan, air being admitted to the fire through openings in the upper surfaces of the bars.

HOLLOW-MILLS. Hollow-mills are used for reducing the diameter of round stock and are frequently employed in connection with spring screw threading dies, taking a cut preceding the die. Hollow-mills are usually made adjustable, the adjustment being obtained with a clamp collar the same as in spring screw threading dies.

HOLLY METHOD. This is a method of operation of Bessemer converter plants in which the burned-out converter is removed by a crane or car and one that has been lined and dried in a separate shop is substituted for it.

HOMO-POLAR MACHINE. See Acyclic Machines.

HONES FOR CYLINDERS. A " cylinder hone " is a special form of abrasive tool used either for re-sizing slightly scored cylinders or for imparting a fine finish to cylinders after either boring, or boring and reaming. As ordinarily designed, a cylinder hone has four narrow strips of abrasive which are held parallel to the cylinder axis by links or arms connecting with a central body or shaft. These arms are hinged or otherwise pivoted, so that the strips of abrasive are free to move outward or radially, thus making contact with the cylinder wall. The pressure of the abrasive against the cylinder wall may be governed entirely by centrifugal force, as the cylinder hone revolves, or, spring pressure may be employed, the arrangement varying according to the design. Unless cylinders are only slightly scored, they should be rebored before honing, as the latter process is adapted only for removing a slight amount of metal, 0.001 to 0.0015 inch being a common allowance for rebored or reamed cylinders. The honing process is applied particularly to automobile motors or other comparatively small internal combustion engine cylinders.

HONING MACHINES. The honing method of finishing automobile cylinders involves the use of abrasive stones which are brought into contact with the previously machined bore, either by a combined rotary and longitudinal motion or by a lengthwise movement. Thus, in some shops the hone is given a fairly rapid rotative motion and a slow lengthwise travel, whereas in others the hone is rotated slowly but is moved rapidly in a lengthwise direction. A third method consists in traversing the hone through the bore without rotation, except at the completion of each stroke, when there is a small but unequal movement.

One design of honing machine reciprocates the hones hydraulically. As there is a wide difference of opinion as to the proper ratio of spindle rotation to spindle reciprocation, wide ranges of rotary and reciprocating speeds have been provided. This type of machine is made in single- and multiple-spindle designs.

HOOK BOLT. See Bolts.

HOOKE'S COUPLING. Hooke's coupling, generally known as the " universal joint," is employed for connecting two shafts, the axes of which are not in line with each other, but which merely intersect at one point. Sometimes two shafts, the axes of which are in different planes, and, hence, do not intersect at any point, are connected with an intermediate shaft which is joined to each of the two shafts by universal joints. Many designs of flexible shafts are simply a combination of a great number of universal joints.

" HOOKING UP " A LOCOMOTIVE. When starting a train, the engineer places the reversing lever all the way forward (if moving in that

direction); the valve then receives the full motion from the eccentric or "eccentric crank" which operates it, the cut-off occurs at the latest point, and the power of the locomotive is maximum. When the train gets under way, the reverse lever is "hooked up" toward the center, thus shortening the travel of the valve, which causes an earlier cut-off; consequently, there is greater expansion of the steam and less steam consumption. The power is reduced, but, since the train is under way, less power is required.

HOOK-TOOTH SPROCKET. This is a sprocket for link-belting, used to transmit power from or to a chain running in a straight or nearly straight line. It is sometimes employed as an idler for returning a horizontal slack chain, if the drive is intermittent and there is a tendency for the chain to jump off an ordinary sprocket.

HORNING AND WIRING PRESS. Presses of this general type are used in the manufacture of tin pails, coffee pots, baking pans, and similar articles. For many operations on such parts, the work must be inserted over a projecting arm or horn which may be either cylindrical, tapering, square, or of a special shape. While supported by this horn or die, the operations are performed by the punch.

HORSEPOWER. In mechanics, *work* is the product of force by distance, and is expressed by a combination of units of weight (force) and distance, as inch-pounds, foot-pounds, foot-tons, etc. *Power*, in mechanics, is the product of force by distance divided by time, or the performance of a given amount of work in a given time, and is expressed as inch-pounds per minute, foot-pounds per minute or second, etc. The term *power* is frequently used by writers on mechanics to designate a *force*. In connection with the so-called "mechanical powers" — the lever, wheel and axle, wedge, screw, etc. — it is usual to speak of the applied force as the power; this is, however, not strictly correct, as power should always, in mechanics, be used in accordance with the definition given above. *Horsepower* (abbreviated H.P.) is the unit of power adopted for engineering work. One horsepower is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second.

The *metric horsepower*, used in countries where the metric system is employed, is equal to 75 kilogrammeters per second, or 542.5 foot-pounds per second, or 32,550 foot-pounds per minute. The *kilowatt*, used in electrical work, equals 1.34 horsepower; or one horsepower equals 0.746 kilowatt. The horsepower unit was introduced by James Watt, the great improver of the steam engine, for the purpose of designating the power developed by his engines. It is said that he had ascertained by experiments that an average cart horse could develop 22,000 foot-pounds of work per minute, and being anxious to give good value to the purchasers of his engines he added 50 per cent to this amount, thus obtaining (22,000 + 11,000) the 33,000 foot-

pounds per minute unit by which the power of steam and other engines has ever since been estimated.

Electrical Equivalent. — The British Association for the Advancement of Science adopted, as early as 1873, 746 watts as the equivalent of the British and American horsepower, and 736 watts as the equivalent of the metric or Continental horsepower. In a circular issued by the United States Bureau of Standards, it is stated that in all future publications of this bureau the former value, 746 watts, or 0.746 kilowatt, will be used as the exact equivalent of the English and American horsepower. For scientific work, it is quite important to have the horsepower thus standardized by being expressed in the so-called "absolute system of measurement," because the common definition of 550 foot-pounds per second is scientifically correct only at a certain latitude and altitude, on account of the fact that the pound-weight, as a unit of force, varies in value as g, the acceleration of gravity, varies. The horsepower when expressed as 746 watts is equal to 550 foot-pounds per second at 50 degrees latitude and at sea level. See Steam Engine Horsepower Rating.

HORSEPOWER, BELTING. See Belt Power-transmitting Capacity.

HORSEPOWER, BOILER. See Boiler Horsepower.

HORSEPOWER, METRIC. See Metric Horsepower.

HOSE COUPLINGS. Hose couplings for $2\frac{1}{2}$-, 3-, $3\frac{1}{2}$-, and $4\frac{1}{2}$-inch sizes have been standardized and adopted by the American Waterworks Association, the New England Waterworks Association, the National Firemen's Association, the National Fire Protection Association, etc. The $2\frac{1}{2}$-inch hose coupling is the size most generally used by public fire departments. The 3- and $3\frac{1}{2}$-inch sizes are used mainly for high pressure or fire-boat services and are not in general use. The $2\frac{1}{2}$-inch size has $7\frac{1}{2}$ threads per inch, the 3-inch and $3\frac{1}{2}$-inch sizes have 6 threads per inch, and the $4\frac{1}{2}$-inch size 4 threads per inch. The threads are the 60-degree form with 0.010 inch cut from the top and the same amount left at the bottom of the groove on the $2\frac{1}{2}$-, 3-, and $3\frac{1}{2}$-inch sizes; and 0.020 inch cut from the top and left on the bottom on the $4\frac{1}{2}$-inch size.

For sizes under $2\frac{1}{2}$ inches, there are several so-called "standards" such as the Eastern gage hose thread (used in the New England States); Pacific Coast hose thread, known also as the California standard hose thread (used on the Pacific Coast); Pittsburg hose thread; Boston hose thread; and the iron pipe thread, which is the general standard for pipe threads.

HOT BEARINGS. Investigation has shown that the main reasons for excessive heating of babbitted bearings are: 1. Shrinkage or contraction of the babbitt. 2. Shrinkage strains set up in the babbitt metal liner by

the unequal distribution of the babbitt metal over the shell. 3. A lack of contact between the babbitt metal liner and the cast-iron or cast-steel shell. 4. The lubricant becomes partially deflected into the wrong place.

HOT-PRESSED BRASS PARTS. Hot-pressed parts are formed in dies by means of a press which exerts enough pressure on a heated slug of forgeable brass to cause the metal to flow and fill the die cavity. The term "hot pressing" is generally applied when some type of power press or hydraulic press is used, whereas, if brass parts are formed in dies under a drop-hammer or steam hammer, the process is known ordinarily as brass forging. Both methods produce die-formed brass parts to replace small brass castings or machined parts such as are produced on screw machines or turret lathes.

The brass slugs, prior to hot-pressing, are heated in a gas, oil or electric furnace to a temperature of about 1450 degrees F.; then the heated slug is inserted in the die and the part is pressed. The pressed pieces are usually subjected to a pickling process to produce a glossy bright surface; they resemble die castings and the surfaces, in many cases, are smooth enough to permit polishing without previous grinding. Hot-pressed parts can be held to limits of plus or minus 0.002 inch on a diameter not exceeding 1 inch. On a diameter of from 1 to 2 inches, the sizes will vary by plus or minus 0.004 inch. Smaller sections than 1 inch can be held closer. Shoulders can be held to plus or minus 0.002 inch.

Alloys for Hot Pressing. — Brass containing 60 per cent copper and 40 per cent zinc is quite forgeable and suitable for the manufacture of hot-pressed parts. The extruded brass shapes now on the market are also suitable for hot pressing; moreover, if the cross-section selected conforms approximately to the shape of the die, the forging of the slugs is facilitated. The slugs, however, should not conform too closely to the shape of the finished forging because the metal must flow under pressure to get the best results. Other metals which can be hot pressed include aluminum, dur-aluminum, monel metal, and similar compositions of a forgeable nature.

Presses Used. The percussion press, which has a screw-operated slide and a friction drive, is particularly adapted to hot-pressing of brass and steel parts. The friction drive gradually accelerates the flywheel (located at the upper end of the screw) and the cumulative quality of the blow delivered causes the heated slug to flow and completely fill the die cavity. The part is finished with one stroke of the press and the slide returns automatically to its upper position.

Both single- and double-acting crank presses, and hydraulic presses, have also been used for hot pressing.

Dies Used for Hot Pressing. — Hot-pressed brass parts may be produced in three types of dies. *Open dies*, similar to those used in drop forging, may be employed, but the forged parts have a flash or fin which must be removed

by trimming. In using *extrusion dies*, the material is confined and forced by the punch to pass through a smaller opening in the bottom, assuming that the forging has a large head and a small stem. In forging a shell or bushing, the metal can be forced to rise up around the punch. *Confined dies* represent the third type. The descending punch closes the die and the metal is compelled to flow in all directions, thus filling the die cavity. It may be necessary to make confined dies in sections in order to remove the finished piece. For some work, there is an advantage in lubricating the dies. See Brass Forging and Hot-pressed Steel Parts.

HOT-PRESSED SOFT-BASE BEARINGS. Bearings for automobile and stationary engines, electric motors, compressors, pumps, etc., may be hot-pressed from soft-base metals. The metals are pressed at a temperature that is low enough to leave their physical characteristics unchanged. The use of stock in the solid state is claimed to prevent segregation of the elements in the metals and to eliminate blow-holes, fissures, and strains. Machining operations are not required, because the bearing is turned out from the press ready for service. The hydraulic press used in forming these bearings in one plant has a rapid approach to the work of 100 inches per minute, and a quick return of 200 inches per minute. Ten strokes, 6 inches long, can be made per minute at a pressure of 200 tons. The pump that actuates the press is equipped with a pressure variometer by means of which the line pressure can be conveniently adjusted between 300 and 1000 pounds per square inch.

HOT-PRESSED STEEL PARTS. A hot-pressing process similar in principle to that employed in hot-pressing brass parts (see Hot-pressed Brass Parts) may be applied to a variety of small steel parts. In hot-pressing steel, the slugs of steel are heated to about 1800 degrees F. and are then pressed to the desired shape in tungsten steel dies having cavities corresponding to the form required.

The production of chrome-vanadium and chrome-nickel gears for automobile transmissions is an example of hot-pressing as applied to steel. One gear having 25 teeth of 7 diametral pitch and a face width of $\frac{3}{4}$ inch is made from a cylindrical slug $2\frac{1}{4}$ inches in diameter and about $1\frac{3}{4}$ inches long. Another gear or pinion having 17 teeth of 7 diametral pitch and a face width of $\frac{13}{16}$ inch is made from a slug $1\frac{3}{4}$ inches in diameter and $\frac{3}{4}$ inch long. These gears are produced singly at an average rate of about ten per minute, although higher production rates could be obtained by using dies designed for making two or more gears simultaneously.

Bevel gears, as well as spur gears, can be produced by hot pressing. The examples mentioned have the teeth formed to the approximate shape and they are produced at one blow on a percussion press which delivers a pressure

of 400 tons. The dies have tungsten steel inserts which are backed up by machine steel.

HOT TOP. In the manufacture of steel, the molten metal from the crucible, converter, or electric furnace is poured into ingot molds. The impurities which float on the top of the molten metal are carried to the top of the mold, which is fashioned with a temporary "hot top" made of some refractory material. By this means the top of the ingot containing the impurities can be sheared off after the ingot is cold.

HOT-WELL. "Hot-well" is the name given the reservoir that receives the cooling water and the condensed steam from a jet type of condenser, or the condensed steam from a surface condenser. The hot-well need not be closed tight, as there is no pressure in it, and it simply serves as a cistern for holding the warm water discharged from the condenser. The feed pump for the boiler of a condensing engine draws water from the hot-well. In land practice, the hot-well is usually arranged with an overflow so that the excess of water not needed by the boiler may escape.

HOT-WIRE METER. This is an instrument for measuring electric current in which the current passes through a straight wire, the amperage being measured by the expansion of the wire caused by the heating effect of the current. The expansion is transmitted by a lever to an indicating needle.

HOYLE'S METAL. Hoyle's metal is a bearing metal of the lead-tin-antimony alloy class, composed of 42 per cent of lead, 46 per cent of tin, and 12 per cent of antimony. The comparatively high percentage of tin makes it an expensive metal, but it is claimed to have good bearing qualities.

HUBBARD BOOSTER. This is an electrical machine of the motor-generator class employing a regulating coil carrying a definite shunted portion of the generator load. This coil forms the field of an auxiliary exciting machine, and is usually mounted on the same shaft with the booster generator and driven at virtually constant speed by a motor. It is used for the charging of storage batteries.

HUBBELL BATTERY. The Hubbell battery is an alkaline storage battery using nickel hydrate for the active material of the positive plate, cadmium for the negative plate, and a solution of potash in water for the electrolyte.

HUB METHOD OF DIE-SINKING. The "hub" or "hob" method has long been employed for making dies such as are used in producing coins, medals, and various products of the silversmithing and jewelry trades. A hub is used, which is in the form of a punch and has a shape corresponding

to the impression required in the die. In other words, the hub, at its formed end, is a duplicate in hardened tool steel, of the part to be molded in the die. While this hub must be made accurately and be given a fine finish, it is, of course, much easier to produce than would be a cavity or impression of corresponding shape. Furthermore, after the hub is made, it can be used to advantage in reproducing duplicate impressions in a number of different dies. The hub is hardened so that it will withstand the extremely high pressures employed in connection with the production of dies by this method. In a general way, the method consists in forcing the hub into the unheated die blank by means of hydraulic power so that the shape of the hub is reproduced in the die impression.

HUMIDITY MEASUREMENT. See Hygrometer.

HUMID PROCESS. In assaying, the humid process, also known as the " wet process," is a method of testing alloys, especially for ascertaining the quantity of silver or gold contained. The process consists in dissolving the metals by acids and afterwards precipitating them.

HUNTING. Hunting, in electrical engineering, is a periodic increase or decrease in the speed of synchronous machinery operating in parallel, such as generators or motors. It may be due to several causes, such as irregular action of the prime movers, or a variation of the supply voltage, as caused, for example, by the drop due to a relatively high resistance and reactance in the supply line.

HUNTING TOOTH. When one of two meshing gears is provided with one more tooth than it would have if the numbers of teeth in the two gears were in an even ratio to each other, this extra tooth is commonly known as a " hunting tooth." For example, if a driven shaft is required to revolve three times as fast as the driving shaft, this result could be obtained by using driving and driven gears having 72 and 24 teeth, respectively. Instead of using this exact ratio, many millwrights, when installing cast gears, would use a driving gear having 73 teeth instead of 72, and a driven gear of 24 teeth. These numbers are very close to the desired ratio, but, as they do not have a common divisor, each tooth of one gear will mesh with all of the mating teeth one after the other, instead of meshing with the same teeth continually. The theory is that when the teeth mesh progressively in this manner, thus distributing the wear, all of the teeth will eventually be worn to some indefinite, but comparatively true, shape. To illustrate the action, any two teeth which happen to meet during the first revolution will be separated by one tooth space at the completion of the second revolution, by two tooth spaces at the end of the third revolution, and so on; consequently, one tooth may be said to " hunt " the other, and hence the name " hunting tooth."

HYDRACID. This is an acid which does not contain oxygen, but in which hydrogen unites directly with the principal element.

HYDRAULIC ACCUMULATOR. A hydraulic accumulator is used for the storing of energy to be expended intermittently for power purposes, as in hydraulic elevators, riveters, and other hydraulic machinery. One type consists principally of a vertical cylinder fitted with a plunger to the upper end of which are secured the weights necessary to produce the required pressure. Water is forced into the cylinder by a force pump. This raises the plunger, the weight of which, reacting upon the water, will transmit the pressure to the machinery operated by it. The force pumps which supply the cylinder will, by continuous running, accumulate in the cylinder, during the periods when this is inactive, an amount of energy equal to that expended during the intermittent periods of activity. The type of accumulator in which the plunger is weighted down is known as the *direct* form. Another type, known as the *inverted* type, operates on the same principle, but the cylinder fits over the plunger from above and supports the weights. A special form of accumulator, known as a *hydropneumatic* type, is so arranged that the water within the cylinder compresses air which reacts upon it, thus serving as a substitute for the weights used in the ordinary type of accumulators. Hydropneumatic accumulators are used especially in connection with hydraulic elevators and presses.

HYDRAULIC CLUTCH. This is a clutch in which the hydraulic pressure of water is used to create the friction required for transmitting power from one clutch member to another.

HYDRAULIC JACKS. Jacks of this type are especially adapted for lifting very heavy loads. There are many different designs and sizes that operate on practically the same principle. One of the most common forms of hydraulic jack is the vertical, inside pumping type. The head and interior of the ram form a reservoir from which the liquid is pumped beneath the ram for raising the jack, and to which the liquid is returned in lowering. When the liquid enters the pump from the reservoir, it is forced by the downward stroke of the piston through a lower check-valve into the cylinder and beneath the ram, which is forced upward because the pump is of small size, and owing to the leverage of the operating handle it is possible to exert considerable pumping pressure. The operating lever slips into a socket at the side of the head. This socket is mounted on a shaft which carries a short arm or lever inside of the head to which the pump piston-rod is attached. The Dudgeon *universal jack* has double pumps so that, if the load is light or if the ram must be extended some distance before the heavy load is encountered, the two pumps can be used together until the strain becomes excessive, when one pump is thrown out by a turn of the handle.

HYDRAULIC PRESSES. A hydraulic or hydrostatic press, is a machine by the use of which some forcing or pressing operation is performed by means of power transmitted through confined fluid under pressure. The hydraulic press was invented by Joseph Bramah, an Englishman, who, in conjunction with Maudslay, laid the foundation for the development of modern metal-cutting tools. The hydraulic press, as built by Bramah, was equipped with a stuffing-box and gland for packing the ram. This arrangement, however, retarded the return stroke and caused considerable trouble until Maudslay substituted the self-tightening cup-leather packing for the stuffing-box.

That fluids, when confined and subjected to pressure, follow a definite law, was first discovered in 1653 by a French scientist, Blaise Pascal, who wrote of the results of his hydrostatic investigations in a treatise on the equilibrium of fluids. By the application of Pascal's law, the development of a tremendous force exerted through a short distance becomes possible by the exertion of very small force through a proportionally longer distance. Advantage is taken of this principle in commercial hydraulic press and pump installations.

The press is frequently separate from the pump and may be located at considerable distance from it; the pump may be of any size and type suitable for delivering the necessary volume of water at the required pressure per square inch; pipe lines and valves may connect the pump and press; and accumulators or other machines or apparatus may also be connected to the system; but notwithstanding all these, when hydraulic communication is open from the pump plunger to the press cylinder, Pascal's law governs, theoretically, the relations existing between the press ram and the pump plunger. Practically slight allowances may be required to compensate for losses due to friction of the water in the pipes, friction of packings, leakage, and other minor losses.

The use of hydraulic presses is confined to no particular industry, nor to any particular class of service. Almost any pressure application or any combination of pressure applications may be produced in a suitable hydraulic press. Practical conditions have, however, limited the use of the hydraulic press mainly to machines in which great pressure is a prime requisite, leaving the field of light pressure requirements to be covered largely by mechanical power presses.

HYDRAULIC RAM. The hydraulic ram is used to raise water from a point below the source of supply to a point which may be considerably higher than the level of the spring, reservoir or part of a stream from which the water flows to the ram. The only power required to operate a hydraulic ram is that obtained from the momentum of a moving column of water. The ram is so constructed that the water is allowed to flow intermittently, and each time its movement is suddenly stopped the kinetic energy is changed

to pressure and utilized to force part of the water through a discharge valve and into an air chamber where air is compressed, and aids in forcing a relatively small quantity of the water out through the discharge pipe. When the ram is in operation, the water flows downward through the drive pipe and through the open waste valve *B* (see illustration) until the required velocity is obtained, when valve *B* is automatically closed. During its flow, the water has developed a certain amount of energy or momentum which, when the flow is suddenly stopped, causes the water to overcome the pressure against the top of the discharge valve *S* which opens and allows a portion of the water to enter the air chamber. Immediately, a rebound occurs and for a short interval water flows out through the discharge pipe. As soon as the movement of water in the drive pipe ceases, valve *B* is opened by the action of weight *H* acting through a cam surface at *G* against which lever *E* bears. The opening of this valve causes the water in the drive pipe to again flow rapidly downward and the cycle is repeated.

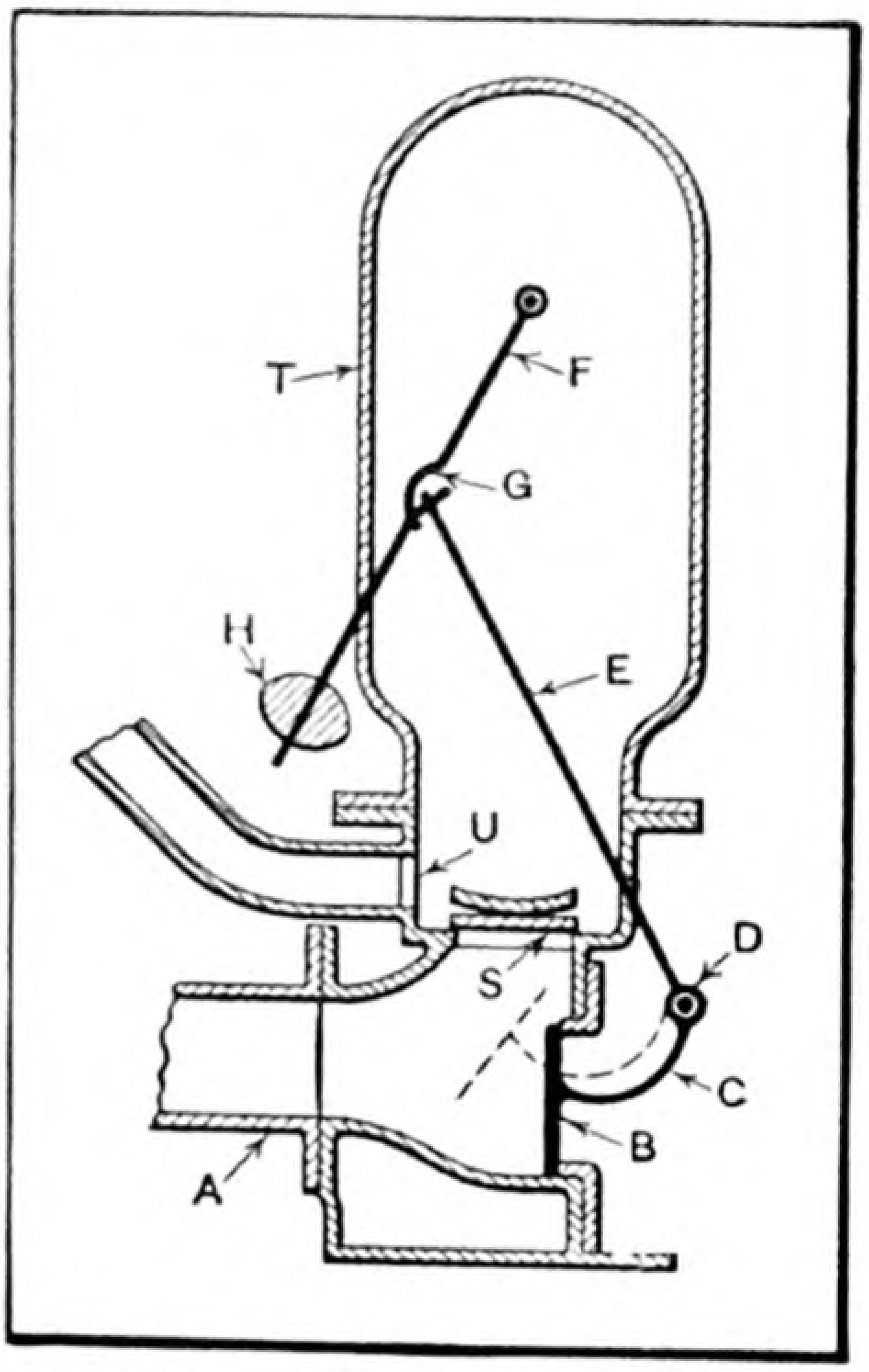


Diagram of Hydraulic Ram

Drive Pipe. — The length of the drive pipe may vary from three to four times the height of the head to eight or ten times the height. According to one rule, if the head or vertical distance from the ram to the level of the source of supply is from 6 to 10 feet, the drive pipe should not be less than six times the height of the fall. If the head is less than 6 feet, the length of the drive pipe should equal from eight to ten times the head. For instance, if there is a head of 5 feet, the drive pipe should be from 40 to 50 feet long, according to this rule. A fall of 2 feet is usually considered about the minimum at which hydraulic rams will operate satisfactorily. The drive pipe should be as straight as possible and the bend near the ram should be a long gradual curve.

Discharge Pipe. — The discharge pipe may vary in length from a few feet to hundreds of feet. Its diameter should vary from one-third to one-half the diameter of the drive pipe. The straighter the pipe line, the better the performance of the ram.

Quantity of Water Delivered. — The amount of water that a hydraulic ram will deliver is affected by the head of water or height of the fall, the

quantity available, the height to which the water is elevated, and the friction in the pipes. In general, it is estimated that approximately one-seventh of the volume of water falling into the ram can be raised to an elevation five times the height of the fall, or one-fourteenth of the volume can be raised about ten times the height of the fall, and so on in like proportion according as the fall or height is increased or diminished.

HYDRAULIC SHEARS. Hydraulic shears which are used in connection with hydraulic intensifiers for giving the required pressure are designed and used for various purposes. Such shears are especially adapted for cutting off billets and blooms in rolling mills, and they are also used for shearing structural shapes.

HYDRAULIC TRANSMISSIONS. Hydraulic transmissions are used in preference to mechanical transmissions on certain types of machines, either to drive the main working member or to provide a feeding movement for a tool or machine table. These hydraulic transmissions consist in general of a hydraulic pump which exerts oil pressure against a driven member which is usually in the form of a piston or plunger enclosed in a cylinder and attached to the driven part; the latter may be a tool-holding slide or work-holding table. This hydraulic mechanism is supplemented by controlling devices intended, in some cases, to adjust the pump output and pressure to whatever constant value is needed to meet normal working conditions. In other installations a pump of different type is designed for rapid and perhaps automatically controlled changes in output or pressure, or both, to regulate, often over a wide range, either the rate of movement or force exerted upon the driven member. Hydraulic transmissions of this kind are now applied to quite a variety of machines and other mechanical devices, including various classes of presses (in preference to fixed-stroke pumps that require accumulators); testing machines; mechanical stokers; cranes and hoists; ships' windlasses and steering apparatus; to certain types of machine tools, etc. In machine tool design particularly, the trend appears to be toward a wider application of the hydraulic transmission, which is utilized in preference to a mechanical transmission partly with the idea of obtaining smoother action and greater flexibility of control. Hydraulic transmissions have been applied to broaching machines for pulling the broach through the work; to grinding machines to provide the traversing movement; to drilling machines, milling machines and some turning machines for supplying the feeding movements.

Reciprocating Motions. — Most hydraulic transmissions are used for driven members which have a reciprocating movement, although some transmissions are also designed to provide rotary motion. A reciprocating drive consists mainly of a rotary type of pump which circulates oil for op-

erating the plunger or ram connected with the driven member. The volume and, in some cases, pressure of the oil may be varied to suit working conditions and reversal of movement at the end of the stroke may be controlled by tappets adjustable for stroke variations, which by operating suitable valves connect the discharge side of the pump with alternate ends of the cylinder in which the driven plunger is located.

Some transmissions are so designed that positive pressures are maintained on both sides of the driven plunger or piston, there being enough difference in pressures to give the required power. This arrangement is to steady the movement and is especially desirable where resistance to the movement of the driven part is liable to vary suddenly. If there are two or more driven members, the hydraulic cylinder of each member must be connected with its own pump if complete individual speed control is required; otherwise it may be practicable to supply all cylinders from a single pump.

When Rotary Motion is Required. — Some hydraulic transmissions are designed to give the driven member a rotary instead of a straight-line motion. This may be done by using a rotary hydraulic motor in conjunction with the hydraulic pump. The hydraulic motor receives the discharge from the pump and its speed is varied by regulating the output of the pump. The working parts of a motor for this purpose may be identical with those of the variable-stroke pump used. The motor may transmit motion to the work-table of a machine through an ordinary pinion and gear drive or through a pinion and rack in case the machine has a reciprocating movement. The rotary type of hydraulic transmission has been applied to large face grinders, to rotary milling machines and to other types of machinery.

Types of Pumps Used. — Oil is invariably employed for hydraulic transmission and the pump used may be either of the gear type or of the multiple-plunger type. The *effective* output from pumps of the gear type may be varied by some by-pass control, whereas the multiple-plunger pump is arranged to vary the stroke and, consequently, the output. The gear pumps ordinarily supply a constant volume of oil at constant pressure, whereas the multiple-plunger type are designed for pressure variations from zero up to hundreds or even thousands of pounds per square inch. The constant volume and pressure principle is utilized when the resistance to the movement of the driven member and its speed, during normal operation, are practically constant, whereas the system adapted for rapid volume and pressure variations is needed where resistances and rates of movement are subject to more or less change under normal working conditions.

Advantages of Hydraulic Transmissions. — Transmissions of the hydraulic type may be used in preference to mechanical transmissions because of one or more of the following advantages, depending upon the type of machine: (1) Greater flexibility of control; (2) quick reversal of motion with practi-

cally no shock; (3) "slip" which compensates for overloads or unexpected obstructions; (4) practicability of locating transmission members with reference either to power application or the design of other parts; (5) use of relief or control valves to safeguard against overloading.

HYDRAULIC VACUUM PUMP. This is an air pump which removes the non-condensible vapors from a condenser by hurling jets of water, approximately rectangular in cross-section, at a high velocity from a revolving wheel. The water jets rush through the discharge cone and diffuser in the form of a helix enclosing the vapors, which enter around the revolving wheel, between the jets or pistons of water. The hurling water is delivered under pressure by a centrifugal pump.

HYDROCARBON. Hydrocarbon is a general name for a number of chemical combinations of carbon and hydrogen, such as marsh gas, tar, pitch, naphtha, etc.

HYDROCHLORIC ACID. Hydrochloric acid, also known as muriatic acid, is an aqueous solution of hydrogen chloride (chemical formula, HCl). In the mechanical industries it is used either alone, or mixed with other acids as an etching fluid. It is colorless when pure, but the commercial acid has a yellow tint, due to impurities. Concentrated acid contains 32 per cent of hydrochloride and has a specific gravity of 1.16. Dilute acid, containing about 18 per cent of hydrochloride, has a specific gravity of 1.09. Hydrochloric acid gives off poisonous fumes if left open in the air, the fumes being chlorine gas. An antidote for chlorine gas poisoning consists of powdered chalk or soap dissolved in water.

HYDROFLUORIC ACID. Hydrofluoric acid is an aqueous solution of anhydrous hydrogen fluoride (chemical formula, HF). The acid dissolves glass, and can, therefore, be used as an etching fluid for glass, a purpose for which it is commonly employed. It also attacks most metals, and can be used as an etching fluid for metal objects as well. The acid is a colorless fuming liquid, having a specific gravity of 1.25, when in a saturated solution. Gases given off by hydrofluoric acid are poisonous, and the acid also is injurious, if applied to the skin. As it dissolves glass, it is generally kept in lead-lined vessels. Hydrofluoric acid is also used for a quick pickle for hot castings. It is also used in conjunction with soda, as a water softening compound for boiler feed water. The acid attacks practically all materials that could be used as containers for it except lead, platinum, gutta-percha, and some clays. When etching glass by means of this acid, the glass is first coated by a light coating of melted paraffin or an etching varnish made from asphaltum and beeswax. In making this varnish the wax is first melted and the asphaltum stirred into it, after which the mixture is boiled until, upon cooling, it will harden readily.

HYDROGEN. Hydrogen is a gaseous chemical element, the symbol of which is H, and the atomic weight, 1.008. The specific gravity, as compared with air, is 0.0694. Its specific heat equals 3.40. It becomes fluid at a temperature of −252 degrees C. (−421 degrees F.), and solidifies at a temperature of −258 degrees C. (−432 degrees F.). Hydrogen is one of the chemical constituents of water, oxygen being the other constituent. Hydrogen burns with a pale blue non-luminous flame at high heat, the oxy-hydrogen flame being used in autogenous welding and in flame-cutting processes. With air or oxygen, hydrogen forms a highly explosive mixture, especially in the proportion of two volumes of hydrogen to one volume of oxygen. It is, therefore, important to take care that free hydrogen does not mix mechanically with air or with free oxygen. Hydrogen is produced commercially as a by-product in the production of oxygen by the electrolytic method.

HYDROGEN BRAZING. See Brazing, Hydrogen Process.

HYDROLINE. Hydroline or "hydrolene," as it is sometimes called, is a trade name given to the petroleum pitch which remains after the cracking of petroleum oil. This pitch is usually graded as soft, medium, and hard. according to the melting point which ranges from 50 degrees centigrade to 150 degrees centigrade and higher.

HYDRO-METALLURGICAL PROCESS. This process, also known as *wet process*, is a method for obtaining a metal from its ore by dissolving the ore in a solution from which the metal can be precipitated. This method is applied to copper ores of low grade containing only from $\frac{1}{4}$ to 1 per cent of copper. The copper obtained by the precipitation is known as *cement copper*.

HYDROMETER. The hydrometer may be defined as an instrument for determining the density or specific gravity of a liquid. Special hydrometers are also used for other purposes. Classified in the broadest sense, there are two types of hydrometers; namely, hydrometers proper and hydrometers that are combined with thermometers, generally known as "thermo-hydrometers." Hydrometers proper may be divided into four specific classes: (1) Density hydrometers, which indicate the density of a liquid on a given scale. (2) Specific-gravity hydrometers, which indicate the specific gravity or relative density of a liquid as compared with water. (3) Per cent hydrometers, which indicate the percentage of a substance in a mixture or solution with water. (4) Arbitrary-scale hydrometers, which indicate the concentration or strength of a liquid on an arbitrarily defined scale. This latter class includes the well-known Baumé type of hydrometer. The hydrometer consists of a glass tube having a weight at one end, so that it

will float in a vertical position in the liquid the density of which is to be measured. The glass tube is provided with graduations on which the density is read off. When reading a hydrometer, the liquid is placed in a glass jar or cylinder, and the hydrometer carefully immersed in it to a point slightly below that to which it would sink by itself, and is then allowed to float freely. The reading should not be taken until the liquid and the hydrometer are fully at rest. The reading should be taken with the eye placed exactly in the plane of the surface of the liquid.

HYDRO-PNEUMATIC ACCUMULATOR. This is a hydraulic accumulator in which the water within the cylinder compresses air which reacts upon it, thus serving as a substitute for the weights used in the ordinary type of accumulator. This type is used especially in connection with hydraulic elevators and presses.

HYDROSTATIC JOINT. This is a type of joint used in large water mains, in which sheet lead is forced tightly into the bell of a pipe by means of the hydrostatic pressure of a liquid.

HYDROSTATIC TEST. A hydrostatic test is a test to which tubing is sometimes subjected, consisting in subjecting it to an internal hydrostatic pressure.

HYGROMETER. The hygrometer is an instrument for measuring the absolute or relative amount of moisture or humidity in the atmosphere. When the instrument is used only to determine changes in the humidity, it is termed a "hygroscope." The instrument depends usually upon the contraction or extension of certain substances when exposed to varying degrees of moisture. The contraction of a substance with an increase in humidity, for example, can be recorded on a scale, and thus indicate the relative amount of moisture in the atmosphere.

HYPERBOLA. The hyperbola is a geometrical curve formed by a plane which intersects a cone parallel to the axis of the cone; hence it has two open branches, each extending to infinity, the principal characteristic of which is that the difference between the distances from any point on the hyperbola to two points on its major axis, known as *foci*, is constant.

HYPERBOLIC LOGARITHMS. Hyperbolic, natural, or Napierian logarithms are used in many calculations, especially those involving the mean effective pressure in steam engine cylinders. The hyperbolic logarithms are usually designated "hyp. log." Sometimes hyperbolic logarithms are also designated "$\log_e$" and "Nap. log." To convert hyperbolic logarithms into common logarithms (having 10 for a base), multiply the hyperbolic logarithm by 0.43429. To convert a common logarithm to a hyperbolic logarithm,

multiply the common logarithm by 2.30258. Hyperbolic logarithms are used extensively in higher mathematics.

HYPER-EUTECTOID STEEL. If the carbon content of steel exceeds about 0.90 per cent it will consist of pearlite plus free cementite and it is known as hyper-eutectoid. See Eutectoid Steels; *also* Steel, Constituents or Structure.

HYPOCYCLOID. A hypocycloid is formed by the path of a point on the circumference of a circle which rolls on the inside of the periphery of another circle. This curve is used for part of the tooth shape of cycloidal gear teeth, part of the tooth shape being formed by an epicycloid, which is the curve formed by the path of a point on the circumference of a circle which rolls on the outside of the periphery of another circle.

HYPO-EUTECTOID STEEL. This is a steel which has a carbon content lower than about 0.90 per cent, and which is composed of ferrite and pearlite, the latter being an intimate mixture of ferrite (pure iron) and cementite (carbide of iron). See Eutectoid Steels; *also* Steel, Constituents or Structure.

HYPOID GEARS. Hypoid gears are tapered gears with offset axes, which in general, look like spiral bevel gears. The tooth action of hypoid gears combines the rolling action of spiral bevel gears with a percentage of endwise sliding. The chief advantages of hypoid gears are noiseless operation, increased load-carrying capacity, the possibility of high reduction and low numbers of teeth, long life, and high efficiency. The axis of the pinion is offset from the axis of the gear by an amount that varies with the diameter and the ratio. The direction of offset determines the hand of the spiral. In rear-axle design, a pinion below center will have a left-hand spiral, while a pinion above center will have a right-hand spiral. The position below center is preferable for two reasons: First, the axial thrust resulting on the pinion on a forward drive is directed away from the gear, and heavy loads tend to move the pinion out of mesh rather than draw it in; Second, the contact between mating tooth surfaces is more intimate on the drive side.

Tooth Loads. — In computing the tooth loads of a pair of hypoid gears, the circumferential or tangential tooth load P of the gear at the center of the face may be determined from the known torque, and the pressure P_n or load normal to the tooth surface is then determined by dividing by the cosine of the normal pressure angle a and by the cosine of the spiral angle hg of the gear. Thus

$$P_n = \frac{P}{\cos a \times \cos hg}.$$

This amount P_n is the total tooth load, or, in other words, the resultant of all components. It is noted that this total tooth load is only slightly

larger than the effective circumferential or tangential tooth load P of the gear, for if we introduce as average amounts $a = 17\frac{1}{2}$ degrees and $hg = 8$ degrees, we obtain:

$$P_n = 1.06\ P - \text{an increase of 6 per cent.}$$

In spiral bevel gears, the total tooth load P_n is considerably larger than the effective tangential tooth load. If a pressure angle of $17\frac{1}{2}$ degrees and a spiral angle of 35 degrees is assumed, the total tooth load is as follows:

$P_n = 1.28\ P$ — an increase of 28 per cent, as compared with 6 per cent for hypoid gears.

HYSTERESIS. When the iron core of an electromagnet is magnetized by a current flowing first in one direction and then in the opposite direction, there is an energy loss known as hysteresis. It is the frictional resistance to the turning around of the iron molecules which takes place during magnetization or reversal of magnetization. Thus after the iron has been magnetized by a current of electricity flowing in one direction, the iron will not, of itself, return to its normal condition, but requires additional energy to accomplish this, and, if a rapid reversal of magnetism takes place continuously, it will be found that a considerable amount of energy has been absorbed. The effect is especially noticeable in iron subjected to rapidly alternating magnetizing forces, as in generators and in transformers. It varies with the frequency and the 1.6th power of the intensity of induction. "Aging" is the term used for expressing the increase in hysteresis loss in core laminations of electrical machines from the continued magnetic reversals at comparatively high temperatures during commercial operation. To prevent aging, silicon steel containing from 2.5 to 4 per cent of silicon is used. This steel has a much lower hysteresis loss than ordinary carbon steel. It is extensively used in transformer cores.

I-BEAM. A name indicating the shape of one of the standard structural sections which is widely used in building construction and for many other kinds of structures. See Structural Shapes.

IDLER GEAR. An idler or intermediate gear simply transmits motion from one gear to another but it has no effect on the speed ratio, or the number of revolutions made by a driven shaft in a given time. This would also hold true if there were several intermediate gears. An idler, however, does change the direction in which the driven gear revolves. When driving and driven gears are located on fixed centers and when their sizes must be varied to obtain different speed ratios, an adjustable idler may be used as an intermediate transmitting member.

IDLER PULLEY. Some belt drives have an idler pulley bearing against one side of the belt to take up slack and also increase the arc of contact, especially on the smaller pulley. The idler of a Lenix or short-center belt drive is mounted on a pivoted weighted arm, and the belt, which is given plenty of slack, is automatically maintained at constant tension. This feature, in conjunction with the increased arc of contact, lengthens the life of the belt and greatly increases its driving power. Idler pulleys (also called " mule pulleys ") are also used in conjunction with right-angle or other belt drives where the change in direction makes it necessary to support and guide the belt over pulleys.

IGNITION SYSTEMS, GAS ENGINE. There are two systems of gas engine ignition (for either of which a magneto may be used advantageously). These are known as the *make-and-break* and the *jump-spark* systems. The spark or flash in the former is obtained by sending a comparatively low-voltage current through a mechanism passing through the cylinder walls. At the proper time, two portions of this mechanism " break contact," and the result of this break in the circuit is a hot flash, which serves to ignite the charge in the cylinder. The same result will be obtained in the open air, if the two terminals of a set of batteries are taken in the hand, connected, and then separated with a " wiping " motion. A bright flash will be seen, which corresponds to the igniting spark of the make-and-break system. This system is used on stationary, portable, and traction engines running below 500 revolutions per minute.

The jump-spark system is in more common use than the make-and-break. When the connection is made, the current jumps across a small gap between two points of the spark plug screwed into the cylinder, and in so jumping, a spark is formed. Although this space is rarely more than $\frac{1}{32}$ inch wide, a high voltage is required, and as the hot gases and compression in the cylinder increase the resistance, it is necessary to furnish a sufficiently high

electromotive force to the current to enable the spark to jump at least half an inch in the open air. This requires a pressure of from 10,000 to 20,000 volts, and, because of the high voltage used, this is known as the "high-tension" system. The make-and-break type of ignition, on account of its lower voltage, is known as the "low-tension" system.

IGNITION TEMPERATURES. The temperature of ignition is the degree of temperature at which a substance will combine with oxygen at a rate sufficiently rapid to produce a flame. The temperature of ignition has often been regarded as the temperature at which chemical combination begins, but this is not correct, because chemical combination has begun before a flame appears. The following temperatures are required to ignite the different substances specified: Phosphorus, transparent, 120 degrees F.; bisulphide of carbon, 300 degrees F.; guncotton, 430 degrees F.; nitroglycerin, 490 degrees F.; phosphorus, amorphous, 500 degrees F.; rifle powder, 550 degrees F.; charcoal, 660 degrees F.; dry pine wood, 800 degrees F.; dry oak wood, 900 degrees F.; illuminating gas, 1110 degrees F.; benzine, 780 degrees F.; petroleum, 715 degrees F.; gas oil, 660 degrees F.; machine oil, 715 degrees F.; coal tars, 930 degrees F.; and benzol, 970 degrees F.

ILLIUM. Illium is an acid-resisting alloy of the following composition: Nickel, 60.65 per cent; chromium, 21.07 per cent; copper, 6.42 per cent; molybdenum, 4.67 per cent; tungsten, 2.13 per cent; aluminum, 1.09 per cent; silicon, 1.04 per cent; manganese, 0.98 per cent; and iron, 0.76 per cent. Carbon and boron are also present in small quantities. The melting point is about 2400 degrees F. The tensile strength of the cast metal is approximately 50,000 pounds per square inch.

IMMERSION BRAZING. This is a brazing process in which the work to be brazed is immersed in liquid spelter solder. It is also known as Dip Brazing.

IMPACT TESTS. Impact tests are made on materials in order to determine their ability to resist shock. A number of machines have been devised for measuring the resistance to impact. One of these, known as the *Charpy impact machine*, consists mainly of a swinging pendulum capable of delivering a blow having a total energy of 30 meter-kilograms (216.99 foot-pounds). The machine is operated by raising the pendulum to an angle of 155 degrees from its lower vertical position. The test specimens are made in the form of bars, 10 millimeters square by 60 millimeters long, notched to a depth of 5 millimeters at the center, the bottom of the notch having a radius of 0.667 millimeter. This test-bar is placed with the ends across knife-edges, the pendulum is released by means of a trigger, and the test specimen

is literally chopped in two, after which the pendulum ascends to an angle depending upon the energy remaining after impact. This angle is registered on a scale. The weight of the pendulum and the height of its center of gravity, before impact, being known, the energy of the blow can be determined. The height of the center of gravity for the angle of ascension after impact being registered, the energy remaining in the pendulum after impact can be determined. The difference is the energy absorbed by the test specimen. This method of testing provides a comparative test of considerable accuracy.

Another type of machine subjects the material to a series of fatigue and impact fatigue tests in such a way that the test piece is not destroyed by one blow. The number of blows required to break a test piece are recorded on a counting device. Different kinds of steel vary greatly in the number of blows required to establish the breaking point, and for this reason the principle upon which the machine is based is a practical one for determining the homogeneity of the metal and its resistance to shock. The machine is set to deliver from 85 to 100 blows per minute. The ram of a given weight, is raised by a cam driven from an electric motor, and then released to fall on the test piece. The number of blows required to break a test piece depends upon the quality of the material being tested, its structure and the heat-treatment that it has received.

IMPEDANCE. Impedance is an abbreviated expression for a certain combination of the physical properties of a circuit. For example, in a circuit containing reactance and resistance:

$$\text{Impedance} = \sqrt{\text{resistance}^2 + \text{reactance}^2}.$$

Impedance may also be defined as the ratio of the voltage to the current in a circuit containing resistance and reactance.

IMPELLER. In a centrifugal pump, the impeller is the rotating element provided with vanes, which draws in air or liquid at the center and expels it at a high velocity at the periphery. There are two impellers in a rotary blower running in mesh with each other.

IMPERIAL BUSHEL. One British Imperial bushel equals 8 Imperial gallons, equals 1.2837 cubic foot.

IMPERIAL GALLON. This is a legal measure of capacity in Great Britain, and is defined as the volume of ten pounds of pure water at 62 degrees F., and equal to one-eighth of an Imperial bushel. The volume of the Imperial gallon equals 277.42 cubic inches, or approximately 1.2009 U. S. gallon.

IMPERIAL WIRE GAGE. The Imperial wire gage is the standard British wire gage authorized by Order in Council, August 23, 1883, as the legal

standard for Great Britain. It is also known as the "Standard wire gage" (abbreviated S.W.G.), as the "New British Standard wire gage" (abbreviated N.B.S.) and as the "British Legal Standard wire gage."

IMPERMEATOR. The impermeator is an instrument or device used in connection with a steam engine for forcing lubricating oil into the cylinder at a uniform rate. This name is used for lubricators of this type to distinguish them from the class of lubricators which supply oil through a wick or by the action of gravity. One type of impermeator consists of a combined receptacle and force pump. A ratchet lever is worked from the valve rod, and this operates a nut fitted to a screw on a plunger. The plunger is thus moved a definite distance for each revolution of the crankshaft, and forces a specific quantity of oil into the cylinder each time the ratchet lever is acted upon.

INCANDESCENT LAMPS. The incandescent lamp is based upon the principle that, when an electric current is sent through a conductor of high resistance, the conductor is heated. If the material for the conductor, the current, the voltage, and other conditions are such that the conductor will be heated until it becomes incandescent and, hence, gives out light, this combination embodies the principle of the electric incandescent lamp. Carbon-filament lamps have been superseded largely by tungsten-filament lamps which are more efficient. Incandescent lamps may be operated on either direct-current or alternating-current circuits, and either in multiple or series.

INCH. A unit of length measurement; 1 inch = 2.54 centimeters = 25.4 millimeters.

INCH, CIRCULAR. See Circular Inch.

INCH-POUND. Torsional tests are made to ascertain the elastic limit and the ultimate torsional strength. Since the strain varies over the sectional area, it is not possible to express the torsional strain as "pounds per square inch," but as "inch-pounds." The latter value is obtained by multiplying the pull applied by the lever arm through which it acts. For instance, assume that a wrench were gripped on a pipe; then, if a pull of 100 pounds is exerted on the wrench at a distance of 10 inches from the center of the pipe, the torsional strain on the pipe would be $10 \times 100 = 1000$ inch-pounds.

INCLINABLE POWER PRESSES. Presses of the inclinable class are so designated from the fact that the upper part of the frame may be inclined to allow finished parts to slide from the die due to the action of gravity. This type of press may also be used with the inclinable member in the vertical position. Inclinable power presses are generally of the gap type. They

are extensively used and are particularly adapted for blanking, piercing, forming, and shallow drawing operations on household utensils, small automobile parts, and many other articles, as well as light embossing operations on jewelry, etc. Presses of this type are generally built in sizes having capacities ranging from two to seventy-five tons. A press of greater capacity than the maximum mentioned would be so heavy as to be difficult to incline by means of the hand-operated mechanism with which these presses are usually furnished.

The inclinable power press is particularly suitable for the automatic production of small parts when it is equipped with a feeding arrangement adapted to the part being produced. For the first operation on a given part the stock is usually fed to the dies in the form of a ribbon or strip by either a single- or a double-roll feed. Very high production rates can be obtained in this manner, it being frequently possible to produce completed or partly completed parts at the rate of 150 per minute. Other styles of feeds used for succeeding operations include dial, hopper, and finger mechanisms. *Inclined presses* have the frame built in a fixed, inclined position, and are thus non-adjustable.

INCLINED PLANE. A plane which makes an oblique angle with the horizontal and which is used to facilitate the moving of bodies, as in the case of a wedge, is classed as one of the "mechanical powers." If μ = coefficient of friction; a = angle of plane, W = weight of body to be moved along plane, and F = force required to move body; then if F acts parallel to the inclined plane and so as to pull the body upward, $F = W(\mu \cos a + \sin a)$. If the movement of the body is down the plane, then $F = W(\mu \cos a - \sin a)$. If the force acts parallel to the base of the plane, then $F = W \tan(a + \theta)$. The coefficient of friction $= \tan \theta$.

INCRUSTATION. The incrustation or scale formed in a boiler, may be due either to the precipitation of mineral substances or to the settling of mud or earthy matter held in suspension by the feed water. See Boiler Scale.

INDEPENDENT CHUCKS. Independent chucks usually have four radial jaws which are fitted in grooves or slots in the chuck body and are adjusted independently by means of screws that are turned by a chuck wrench.

INDEPENDENT CRANE. An independent crane is a jib crane the post of which is so pivoted in the floor foundation and at the top that it is free to make a complete circle about its pivots. This crane is suitable for use in the center of large bays in shops and foundries, as it can serve a wide area.

INDEX CENTERS. Many classes of work that are done on milling machines, especially of the universal and plain column-and-knee types,

require indexing in order to obtain equal spaces or divisions when milling such parts as small gears, ratchets, cutters, taps, reamers, etc. While this indexing is very commonly done with a regular dividing-head of the type which can also be used for spiral milling, what are known as *index centers* are frequently used. These are comparatively simple in construction and are designed for dividing purposes only. There are two general types of index centers which are known as *plain* and *universal* centers. The spindle of a plain type is parallel with the base and is not adjustable, whereas the spindle of the universal type can be set at an angle, the same as a regular dividing-head spindle although it cannot be used for spiral milling. Multiple index centers are often used in preference to the single-spindle type, especially for manufacturing purposes. These centers are used for such operations as fluting taps and reamers, cutting small gears, and for similar work. A common design of multiple index center has three parallel spindles which are geared together and indexed in unison. There are also three footstock centers in alignment with the indexing spindles.

INDEXING. The process of dividing a circular part into equal spaces or divisions by means of an indexing- or dividing-head is known as indexing. There are three systems of indexing known as the plain or simple system, the compound system, and the differential system.

Plain Indexing. — When indexing, if the required division or movement can be obtained by simply turning the index-crank of the indexing or dividing-head the required amount, and engaging it with one of the holes in the index plate, this is known as *plain* or *simple* indexing, because only one indexing movement is necessary, instead of two movements, as with compound indexing.

Compound Indexing. — Ordinarily, the index-crank of a dividing-head must be rotated a fractional part of a revolution, when indexing, even if one or more complete turns are required. This fractional part of a turn is measured by moving the latch-pin a certain number of holes in one of the index circles; but, occasionally, none of the index plates furnished with the machine has circles of holes containing the necessary number for obtaining a certain division. One method of indexing for divisions which are beyond the range of those secured by the plain or simple method is to first turn the crank a definite amount in the regular way, and then the index plate itself, in order to locate the crank in the proper position. This is known as *compound* indexing, because there are two separate movements which are, in reality, two simple indexing operations. The index plate is normally kept from turning by a stationary stop-pin at the rear, which engages one of the index holes. When this stop-pin is withdrawn, the index plate can be turned.

Differential Indexing. — This system is the same in principle as compound indexing, but differs from the latter in that the index plate is rotated by suitable gearing which connects it to the dividing-head spindle. This rotation or differential motion of the index plate takes place when the crank is turned, the plate moving either in the same direction as the crank or opposite to it, as may be required. The result is that the *actual* movement of the crank, at every indexing, is either greater or less than its movement with relation to the index plate. This method of turning the index plate by gearing instead of by hand makes it possible to obtain any division liable to arise in practice, by using one circle of holes and simply turning the index crank in one direction, the same as for plain indexing. In actual practice, the number of turns of the index-crank for obtaining different divisions is usually determined by referring to indexing tables.

INDEXING, BLOCK. See Block Indexing.

INDEXING HEAD. This is an attachment which forms a part of the equipment of all milling machines of the universal type, and of many plain machines. The dividing-head, when in use, is bolted to the table of the machine. It is employed in connection with a footstock when milling work that must be supported between the centers. The dividing-head is also used independently, that is, without the footstock, in which case the work is usually held in a chuck attached to the spindle. By means of the dividing-head, the circumference of a cylindrical part can be divided into almost any number of equal spaces, as, for example, when it is necessary to cut a certain number of teeth in a gear. It is also used for imparting a rotary motion to work (in addition to the longitudinal feeding movement of the table) for milling helical or spiral grooves, and is sometimes called a " spiral head." A great deal of the work done in a universal milling machine requires an attachment of this kind.

Sector. — After withdrawing the latch-pin of a dividing-head for indexing, one might easily forget which hole it occupied, or become confused when counting the number of holes for the fractional turn, and, to avoid mistakes of this kind as well as to make it unnecessary to count, a device called a *sector* is used. The sector has two radial arms which have an independent angular adjustment for varying the distance between them. The sector is used by so adjusting these arms that when the latch-pin of the index-crank is moved from one to the other, it will traverse the required number of holes for whatever fractional turn is necessary.

INDEXING HEAD, OPTICAL. The main feature of the optical dividing head is the means provided to insure accurate settings. There is a glass dial mounted directly on the spindle, and this dial is graduated to 360 degrees around the periphery. While indexing the spindle, the dial graduations

may be observed through a microscope as the hand-wheel is being turned, and when the desired setting has been obtained, the spindle is locked in place. Since the readings are made on a dial mounted directly on the spindle, inaccurate settings cannot result from any lost motion that might occur through wear in the mechanism. Readings are made directly in minutes. The spaces between the degree graduations of the glass dial are magnified sixty times by the microscopic eye-piece, and appear about $1\frac{3}{4}$ inches apart. A second vernier scale of 60 minutes is projected by the ocular into the field of observation, and, as the graduations on this scale appear about 0.03 inch apart, it is safe to estimate settings within 20 seconds.

INDIAN CORUNDUM. This is a natural abrasive obtained from India, which contains about 73 per cent of crystalline alumina, which constitutes the cutting material of the abrasive. As an abrasive, it is better than emery, but is not as good as the Canadian or Georgia abrasive.

INDIAN STEEL. See Damascus Steel.

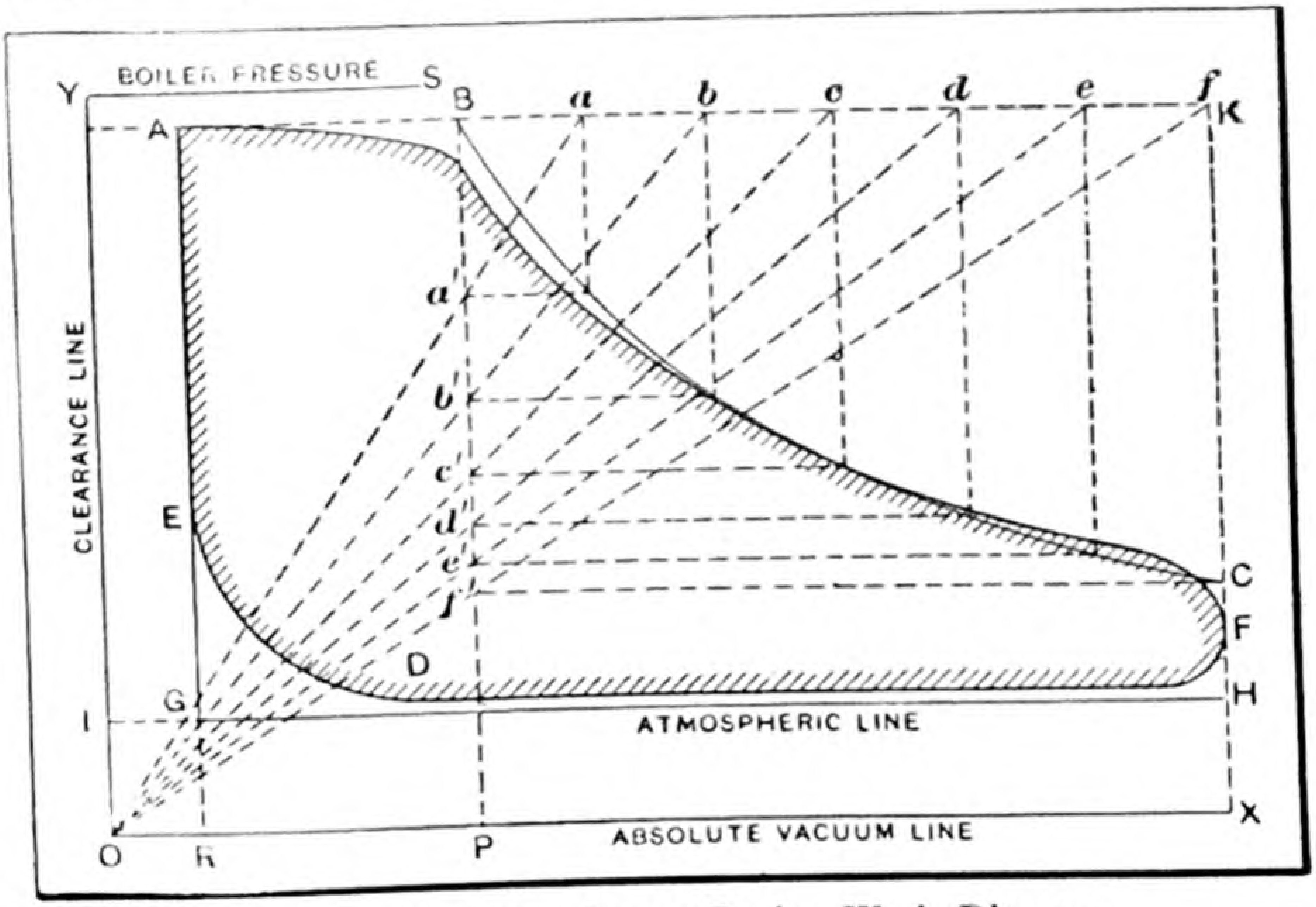
INDIA-RUBBER CEMENT. Same as Hart's india-rubber cement.

INDICATED HORSEPOWER. The actual power exerted by the expanding steam in the cylinder of a steam engine, or the power of the explosion and expansion of the gases in the cylinder of a gas or oil engine, is known as the *indicated* horsepower. The indicated horsepower does not take account of any frictional losses; hence, it is always greater than the brake horsepower. Indicated horsepower is so named because the amount of power developed in the cylinder per stroke is determined by getting the mean effective or average pressure throughout the stroke, from an indicator diagram obtained with an engine indicator. See also Horsepower.

INDICATOR, ENGINE. A diagram may be made to represent graphically the work done in an engine cylinder during one stroke of the piston. An indicator is a device for making a diagram of what actually takes place in an engine cylinder under working conditions. Such a diagram taken from a steam engine cylinder, shows the points of admission, cut-off, and release, and indicates accurately the pressures acting on both sides of the piston at all points of the stroke. The indicator diagram provides means of determining the mean effective pressure, from which the indicated horsepower of the engine can be determined. Such diagrams, taken from engines in service, also show any defects in steam distribution due to improper valve setting. Just how an indicator diagram represents the work done in an engine cylinder will be apparent by considering first the ideal or "work diagram."

Work Diagram. — In mechanics, the product of weight or force acting, times the distance moved, represents work; and if the force is taken in

pounds and the distance in feet, the result will be in foot-pounds. This result may be shown graphically by a figure called a *work diagram*. One of the first steps in the design of a steam engine is the construction of an ideal diagram, and the engine is planned to produce this as nearly as possible when in operation. First assume the initial pressure, the ratio of expansion, and the percentage of clearance, for the type of engine under consideration. Draw lines OX and OY at right angles. (See illustration.) Make OR the same percentage of the stroke that the clearance is of the piston dis-



Construction of a Steam Engine Work Diagram

placement; make RX equal to the length of the stroke (on a reduced scale). Erect the perpendicular RA of such a height that it shall represent, to scale, an absolute pressure per square inch equal to 0.95 of the boiler pressure. Draw in the dotted lines AK and KX, and the atmospheric line LH at a height above OX to represent 14.7 pounds per square inch. Locate the point of cut-off, B, according to the assumed ratio of expansion. Points on the expansion curve BC are found as follows: Divide the distance BK into any number of equal spaces, as shown by a, b, c, d, etc., and connect them with the point O. Through the points of intersection with BP, as a', b', c', d', etc., draw horizontal lines, and through a, b, c, d, etc., draw vertical lines. The intersection of corresponding horizontal and vertical lines will be points on the theoretical expansion line. If the engine is to be non-condensing, the theoretical work, or indicator diagram, as it is called, will be bounded by the lines $ABCHG$.

Indicator Diagram. — The actual diagram obtained with an engine indicator, will vary somewhat from the theoretical, as shown by the shaded

lines. The admission line between *A* and *B* will slant downward slightly, and the point of cut-off will be rounded, owing to the slow closing of the valve. The first half of the expansion line will fall below the theoretical, owing to a drop in pressure caused by cylinder condensation, but the actual line will rise above the theoretical in the latter part of the stroke on account of reëvaporation, due to heat given out by the hot cylinder walls to the low-pressure steam. Instead of the pressure dropping abruptly at *C*, release takes place just before the end of the stroke, and the diagram is rounded at *CF* instead of having sharp corners. The back pressure line *FD* is drawn slightly above the atmospheric line, a distance to represent about 2 pounds per square inch. At *D* the exhaust valve closes and compression begins, rounding the bottom of the diagram up to *E*. The area of the actual diagram, as outlined by the shaded lines will be smaller than the theoretical, in about the following ratio: Large medium-speed engines, 0.90 of theoretical area; small medium-speed engines, 0.85 of theoretical area; high-speed engines, 0.75 of theoretical area.

INDUCED DRAFT. The induced draft system of a power plant has a fan placed between the furnace and the chimney, and the air is drawn through the furnace by suction. This corresponds with the natural draft produced by a chimney, and also permits of the use of an economizer in the main smoke connection. With this arrangement, all leakage is inward and there is no danger of dust and smoke being blown into the fire-room, as with forced draft. On the other hand, a system of induced draft is more expensive to install, because the gases, being at a higher temperature, have a greater volume, and require a higher speed and more power to move them.

INDUCTANCE UNIT. See Henry.

INDUCTION. Induction, in electricity, is the phenomenon by which a body charged with electricity or magnetism, or conducting an electric current, produces an electric or magnetic condition in a neighboring body without direct contact. "Electrostatic induction" is the production of an electrical charge in a body by the influence of another body which is charged with static electricity. "Electrodynamic induction" is the production of an electromotive force in another circuit by the influence of an electric current. When the current is induced by the action of a magnet, or when a magnetic condition is induced by an electric current, the phenomenon is known as "electro-magnetic induction." "Magnetic induction" is the production of magnetic properties in a magnetic substance by another magnet.

INDUCTION CLUTCH. The induction clutch is similar in its operation to an induction motor. One form of induction clutch, applied to an elec-

trically-driven planer, has a copper ring which is the driven member and is held by a spider. This spider runs loose on the shaft and its hub carries a pinion through which power is transmitted. The driving member is keyed to the continuously running motor shaft. This driving member, which acts also as a flywheel, consists of two steel castings bolted together at the hub, a coil, and collector rings. The copper ring has running clearance between the outer rims of the two steel castings which comprise the poles, and, since the copper ring is nonmagnetic, it has no tendency to be drawn over towards the poles on either side. This ring has, however, a high conductivity and, because of this fact and its position with relation to the revolving magnetic driving member, it is pulled along by this driving member on the same principle as that of the induction motor. Two such clutches are employed when used on a planer, one for the cutting and the other for the return stroke, and a switch worked by dogs admits a small current to one clutch on the cutting stroke and to the other clutch on the return stroke. The induction clutch transmits power without contact between its driving and driven members.

INDUCTION MOTORS. Commercial induction motors have a stationary element called the "stator," and a rotating element called the "rotor." The induction motor derives its name from the fact that the secondary member or rotor receives its electrical energy from the primary member or stator by magnetic induction, there being no electrical connection between the stator and rotor windings. The transformer is the most commonly known piece of electrical apparatus, in which one winding receives its electrical energy from a second and independent winding by magnetic induction; hence, it is common practice to consider an induction motor as a transformer with a stationary primary and a revolving secondary. Thus, the stator is often called the "primary," and the rotor, the "secondary." The windings are so placed in the stator slots as to cause a rotating magnetic field to be produced when alternating current is supplied. The rotor of an electric induction motor must revolve at a speed somewhat lower than synchronous, in order that a secondary current and a torque shall be created. The actual speed of an induction motor is, therefore, less than the synchronous speed by a few per cent, called the "per cent slip." The slip increases with the load, thus increasing, by the cutting of lines of force, the current in both secondary and primary windings, and the torque.

High-speed Motors. — The development of the high-speed induction motor for direct application to machine tools has been of great importance to the machine tool industry. Moderate and high-speed motors are now applied to the same machine, the high-speed motor generally being used to drive the cutting tool, and the slower speed motor to drive the feeding mechanism.

High-speed motors are of the same construction as the standard squirrel-cage motors. The speeds of these motors may range from 3600 to 18,000 revolutions per minute, and it would be feasible to obtain higher speeds if required commercially. In high-speed induction motors, the ratings are based on a continuous duty with a temperature rise of 50 degrees C. The motors are designed to operate at either 120 cycles, both 110 and 220 volts, or 200 cycles, 110 volts. Probably the majority of motors used in the machine tool industry are of the two-, four-, six-, or eight-pole type. The synchronous speed of an alternating-current motor is obtained by dividing the number of alternations per minute by the number of poles. For example, consider a two-pole motor operating on a 60-cycle circuit. Sixty cycles is equivalent to 7200 alternations per minute, and dividing this number by 2, the motor speed is found to be 3600 revolutions per minute. Since a motor cannot have less than two poles, 3600 revolutions per minute is the maximum speed that can be obtained on a 60-cycle source of supply. In order to obtain the higher speeds, it is necessary to increase the frequency or the number of cycles per second.

INDUCTION PIPE. The name "induction pipe" is sometimes given to the pipe through which the live steam passes to the steam chest of a steam engine. The opening from the steam chest into the cylinder through which the live steam flows is known as the *induction port*. The *induction valve* is the valve controlling the supply of live steam to the cylinder.

INDUCTION REGULATOR. An induction regulator is a form of transformer, the secondary voltage of which may be varied from maximum to zero and then to maximum in the opposite direction, by changing the relative angular position of the primary and secondary. The induction regulator is used to maintain constant voltage on circuits where constant voltage is important, such as lighting circuits, the varying load of which makes such a device necessary. A small variation in the voltage of a lighting circuit makes a large variation in the luminosity of the lamps, and close regulation is important. The primary is connected across the line and the secondary is connected in series with the line. This type of regulator gives a perfectly smooth change without steps.

INDUCTOMETER. The instrument known as an inductometer is used for measuring the degree or rate of electrical induction, or for comparing the specific inductive capacities of different substances. The device consists of three insulated metallic plates placed parallel to, and at an equal distance from, one another. Each exterior plate is connected with the insulated gold-leaf of an electroscope.

INERTIA, MOMENT OF. See Moment of Inertia; also Polar Moment of Inertia.

INGOTS. After a large body of steel has been refined in an open-hearth furnace of Bessemer converter it is common practice to pour the molten steel into cast-iron molds thus forming ingots of convenient size for subsequent rolling or forging operations.

In *bottom-pouring* an ingot, the metal is poured into a vertical runner and flows up into the mold through an opening in the bottom. As the runner is kept full of metal by the constant flow from the ladle, the level in the ingot mold gradually rises. While all metallurgists and steel makers do not agree that bottom-poured ingots possess the superior qualities which others claim for them, the principal advantages from this method of pouring may be summarized as follows: The metal flows up into the mold very quietly and without any splashing such as occurs when pouring from the top and especially when first beginning to pour into the bottom of the mold. This splashing action which accompanies top-pouring results in a poor surface condition of the ingot. It is also claimed that when pouring from the bottom there is less tendency to entrap dirt or foreign matter in the ingot, as this is carried outward to the surface of the mold when the metal flows up through the opening in the center. Still another advantage claimed for the bottom method of pouring is that there is practically no oxidizing action of the air upon the stream of metal which flows from the ladle. The distance between the bottom of the ladle and the top of the runner is only a few inches, so that there is no time for oxidizing action to occur, which is not the case when the metal is poured from the top and there is a long stream extending from the ladle to the level of the metal in the ingot. Some metallurgists contend that the advantages which might accrue from bottom-pouring are partially, if not entirely, offset by a slagging off of the refractory lining in the runner; others claim that such slagging action can be reduced until it is negligible.

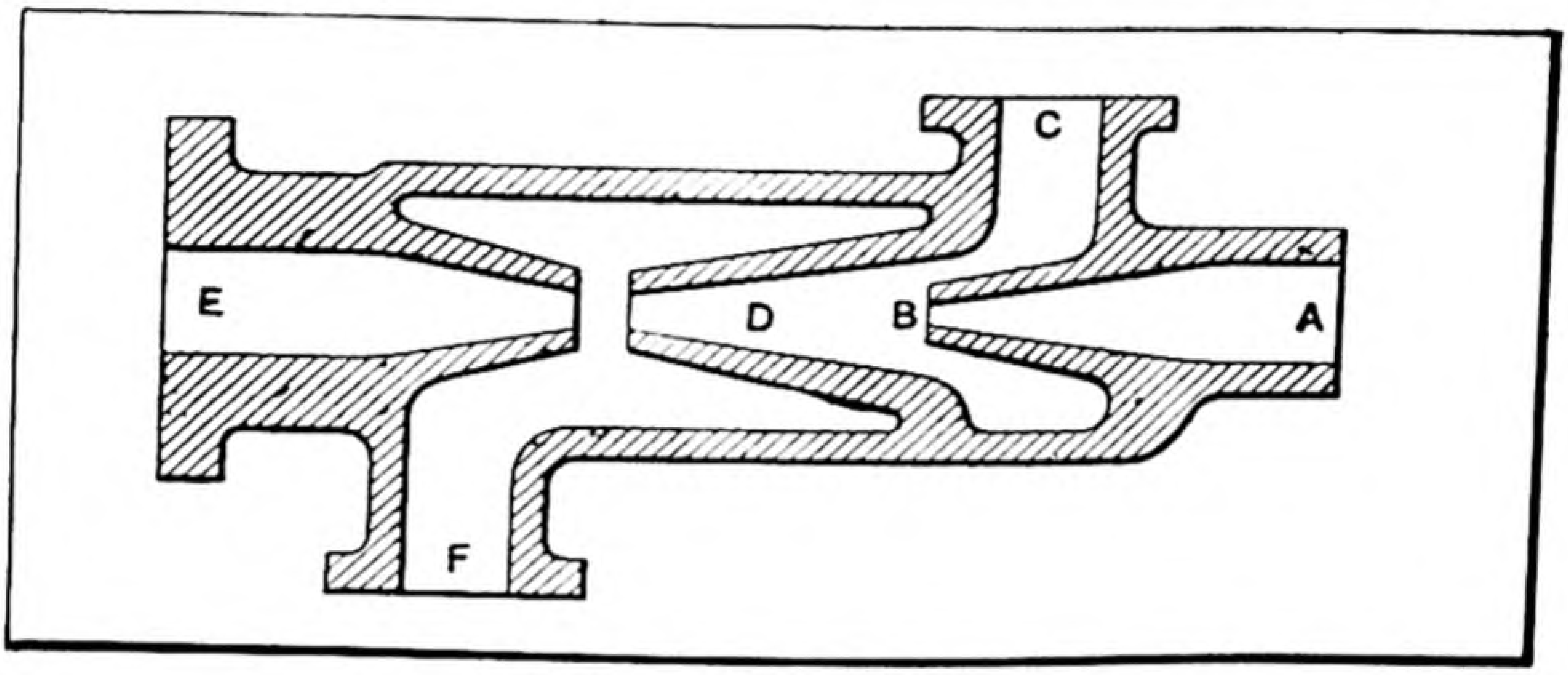
INITIAL PRESSURE. The pressure in the cylinder of a steam engine up to the point of cut-off, is called the initial pressure. It is usually slightly less than boiler pressure owing to " wire-drawing " in the steam pipe and ports.

In air compressors the initial pressure is the pressure from which the air is compressed to a higher pressure. The initial pressure is usually the atmospheric pressure.

INITIAL VOLUME. In air compression, the initial volume is the volume of the air before it has been compressed. This is usually the volume of the air at atmospheric pressure.

INJECTOR. The injector is a device for feeding water to steam boilers, the steam of the boiler itself being used to force water into the boiler against its own pressure. The diagram shows the elementary principle of the action of an injector. The steam from the boiler enters at *A* and passes through

the orifice *B*; the feed water enters through *C* into a chamber which entirely surrounds the steam nozzle. When the stream strikes the feed water, it is condensed, and a vacuum is produced in the chamber *D*; hence, the water is forced with great velocity into and through this chamber, its velocity being increased by the pressure of the steam entering at *B*. When the water expands in the lower part of the nozzle at *E*, it loses velocity, but, according to the laws of hydrodynamics, it gains in pressure, so that it can enter the boiler through a check-valve. The pipe at *F* is an overflow, providing an



Principle of Injector Action

outlet for the steam and water until the velocity and pressure acquired is great enough to force the water into the boiler.

INSPECTION GAGES. Inspection gages are used by the inspector for checking the product. These gages are generally of the same design as the working gages, except that they have a smaller allowance for wear. See Gage Classification.

INSPIRATOR. The inspirator is a device consisting of two combined injectors or a double injector used in connection with a steam boiler. One injector is used for raising the feed water for the boiler from a reservoir and delivering it to the other injector, which forces it into the boiler.

INSTRUMENT METAL. For certain classes of scientific and other instruments, it is important to use a metal which has a very small coefficient of expansion. A nickel steel alloy known as Invar is adapted to work of this kind. See Invar; also Platinite.

INSTRUMENT THREADS. Instrument threads is the name used for a standard screw thread system employed by the Royal Microscopic Society of London, England. It is also known as the " Society " thread, and is employed for microscope objectives and the nose-pieces of the microscope into which these objectives screw. The form of the thread is the standard Whitworth form. The number of threads per inch is 36. A screw thread

system for instruments was also devised by Whitworth. The British Association thread is another thread system employed on instruments abroad.

INSULATION, HEAT. The best insulating materials for preventing loss of heat in steam or hot water pipes are those that hold air confined in minute cells. Incombustible mineral substances are to be preferred to combustible material. No covering should be less than one inch in thickness. Mineral wool, a fibrous material made from blast furnace slag, is an excellent non-combustible covering, but it is brittle and, therefore, likely to be reduced to a powder when subjected to vibration. The percentage of steam lost through a covering of mineral wool about $1\frac{1}{4}$ inches thick is about one-tenth of that lost from bare pipes. A heat insulation composed of a number of layers of asbestos paper in which are imbedded small pieces of sponge is also very effective. The amount of heat lost with the general commercial pipe coverings is from one-eighth to one-sixth of the amount that would be lost with bare pipes. In most cases, it pays to use the best commercial pipe covering obtainable, because often the material is paid for many times over during the first year by the saving effected by its use. Few steam lines at the present time are provided with a covering thick enough for the greatest net saving. However, where fuel is cheap and the lines are in use only a small percentage of the time, the thinner coverings have their advantages. Also, there are places, as on some heating systems, where the heat lost through the coverings is not wasted. Therefore, a careful study of conditions is necessary before a certain type of covering can be recommended. The durability of materials used for pipe coverings is also an important factor in determining the most economical covering for a given set of conditions. The proper basis for comparing costs is the cost per year and not the first cost of the material.

INSULATORS, ELECTRICAL. Materials which are non-conductors of electricity are known as insulators. Insulating materials comprise a large number of substances, varying widely in composition and physical properties. In some instances, materials are required which are highly heat-resistant or arc-proof, as finger shields or arc deflectors in controllers, heating device insulation, etc., whereas in other cases the insulating material must become liquid or soft, or self-healing under heating or arcing, as in high-tension bushings. A definite amount of wear under abrasion is required in certain construction, as in commutators and magneto distributors, but in other cases, there must be a minimum of abrasive wear, as in rheostat dead segments, wire insulation, etc. Heat conductivity is an important requirement in some instances, as in armature coils, but in other insulation, as in heating devices, a minimum heat conductivity gives greatest efficiency. It is obvious, therefore, that in insulating work diametrically opposite properties

are often required in the materials used. It is because of the necessity of meeting these varied requirements that the large number of insulating materials now employed in the electrical industry have been developed.

Porcelain. — As an insulating material, porcelain occupies a field by itself, and probably more of this material is used yearly than of all the other insulating materials combined, with the exception of rubber.

Glass. — Glass, like porcelain, is heat and water resistant, unaffected by oils and vapors, of attractive appearance and high in crushing strength, but somewhat low in transverse and tensile strength. The disruptive strength of glass is about the same as that of porcelain, but falls off more rapidly with rising temperature, and this is true also of the insulation resistance.

Mica. — Mica is the most widely used of the natural insulations and comprises a group of natural silicates distinguished by highly developed basic cleavage into thin, tough, flexible laminæ. Mica is especially valuable for commutator insulation because of its evenly laminated structure, resistance to compression, mechanical toughness, resistance to high temperature and insolubility.

Marble, Slate and Soapstone. — These materials are generally used in slab or plate form for switchboard panels, small switch bases, etc. Soapstone is also machined to form small bushings, beads, and other insulating parts, and, after being thus machined to shape, is fired in kilns to harden the material, in the fashion of porcelain.

Fireclay. — Fireclay products are used in insulating work only to a very limited extent, as in economizers in flame arc lamps, bushings and electrode guides in arc lamps, supports for the heating coils in heating devices, etc.

Molded Rubber. — Rubber is used as an insulating material both in sheet form and as a molded material. Molded rubber insulation may be classified into hard rubber or soft rubber molded parts. The use of hard rubber as insulation in the electrical industry has greatly diminished, as it has been replaced by other materials.

Molded Compounds. — Under this head may be included a large class of compounds which are produced in various required rigid shapes or forms from a plastic mass by means of molds, either with or without pressure.

Sheet Materials. — Under this heading are included a great variety of materials produced in the form of sheets from which the insulation is cut as required. Such insulation may be applied in sheets of varying size, or cut into tapes and applied by the well-known taping operation.

Paper. — Papers of various kinds are used in many ways in insulating work, from the very thin japanese rice paper used to make flexible mica tape, to the heavy papers used as separators in coils of various kinds.

Cloth. — Cloth finds extensive use in the insulation of electrical apparatus, the bulk of it being used as a retaining medium for varnish, it being either

coated with varnish to form varnished cloth, or applied as a dry taping to coils and afterwards immersed or brushed with varnish so that the interstices are thoroughly filled. Cotton cloth is most widely used and includes cambric. muslin, drill, and duck.

Fiber. — Sheet fiber is employed where hardness and mechanical strength are required; where proper treatment or filling of the fiber is accomplished, a considerable degree of insulation may also be obtained. The varieties of sheet fiber commonly used are horn fiber, leatheroid, rawhide fiber, and vulcanized fiber.

Liquid Materials. — A number of insulating materials are prepared in liquid form to be subsequently applied as an improvement of solid, porous, insulating materials, or as an insulation of metallic surfaces, or to serve as insulation between different component parts of a piece of apparatus and at the same time to serve other purposes, as in cooling transformers, preventing arcing in high-tension switches, etc.

INSULUMINUM. Insuluminum is a trade name used for the aluminum alloy by means of which the surface of a metal may be protected against oxidation at high temperatures. The alloy is produced by the process known as *calorizing*, which was developed in the General Electric Co.'s research laboratories.

INTENSIFIER. An intensifier is a hydraulic accumulator consisting of two cylinders of different diameters, the smaller cylinder being contained in the ram or plunger that fits into the larger cylinder. By the use of this machine very high pressures can be obtained.

INTERCHANGEABLE MANUFACTURE. In 1798, Eli Whitney, inventor of the cotton gin, obtained a contract from the government for 10,000 muskets, built a shop in the outskirts of New Haven, and there laid the foundations of the interchangeable system of manufacture. Using limit-gages, milling machines, and rude jigs, he demonstrated that guns could be manufactured by machine tools, not only interchangeably but more cheaply than by the old hand methods. About the same time, Simeon North, a gun-maker in Middletown, Conn., obtained contracts for pistols, and began a connection with the government which lasted for fifty years. A later contract signed by him in 1813 contained the first clause specifying interchangeability; "the component parts of pistols are to correspond so exactly that any limb or part of one pistol may be fitted to any other pistol of the 20,000." It is probable that the North contract of 1813 was not so much the beginning of the new method as the recognition of one which had already come into existence, as the letters of Whitney himself and the reports of Capt. Wadsworth, the government inspector, show clearly that Whitney, at least, had been developing the idea from 1798. The armory which he

founded continued in business for ninety years, when it was sold to the Winchester Repeating Arms Co.

There are several degrees of interchangeability in machinery manufacture. Strictly speaking, interchangeability consists in making the different parts of a mechanism so uniform in size and contour that each part of a certain model will fit any mating part of the same model, regardless of the lot to which it belongs or when it was made. However, as often defined, interchangeability consists in making each part fit any mating part in a certain series; that is, the interchangeability exists only in the same series. Selective assembly is sometimes termed interchangeability, but is merely assembly without fitting. It will be noted that the strict definition of interchangeability does not imply that the parts must always be assembled without hand work, although that is usually considered desirable. It does mean, however, that when the mating parts are finished, by whatever process, they must assemble and function properly, without fitting individual parts one to the other.

When a machine has been installed possibly at some distant point, a broken part can readily be replaced by a new one sent by the manufacturer, but this feature is secondary as compared with the increased efficiency in manufacturing on an interchangeable basis. In order to make parts interchangeable, it is necessary to use gages and measuring tools, to provide some system of inspection, and to adopt suitable tolerances or limits. Whether absolute interchangeability is practicable or not may depend upon the tolerances adopted, the relation between the different parts, and their form. Parts will always interchange if the tolerances are large enough, and the maximum sizes of members such as shafts, etc., do not exceed the minimum sizes of holes which receive them when the machine is assembled; but if the tolerances are too large, the parts may be useless.

INTERCOOLERS FOR COMPRESSED AIR. In compressing air, a great amount of heat is generated due to the friction of the molecules composing the air, which are being crowded into a smaller space. In compressing air to 100 pounds gage pressure, the final temperature, assuming the compression to be adiabatic, would be about 485 degrees F. The effect of this constant increase in temperature is to tend to expand the air under compression to a larger volume, thus necessitating a corresponding increase of work to compress this apparently increased volume. After the compressed air has been discharged into the receiver or pipe line, the temperature rapidly falls to that of the surrounding atmosphere and the energy due to the heat generated during compression is lost. It, therefore, follows that in compressing air to any great extent, a large amount of work is expended due to temperature conditions, and the only method of reducing to a minimum the amount of work lost is to cool the air during the period of compression.

In theory, the air should be kept at a constant temperature during the period of compression; but the attainment of this is a practical impossibility in air compressors. In modern practice, the work of compression is divided equally between two or more stages. The number of stages depends upon the final air pressure required. An "intercooler" is used between the different stages to reduce the temperature of the compressed air to the normal between the stages. An intercooler built in accordance with modern practice consists of a long shell of cylindrical shape containing a nest of tubes through which cold water is circulated. The air enters at one end of the shell from the low-pressure cylinder at a high temperature, passes around and between the nest of tubes, and enters the high-pressure cylinder at the other end at a greatly reduced temperature.

INTERFERENCE BANDS. See Light Wave Measuring Method.

INTERFEROMETER. The interferometer is an instrument of great precision for measuring exceedingly small movements, distances, or displacements, by means of the interference of two beams of light. Instruments of this type are used by physicists and by the makers of astronomical instruments requiring great accuracy. Prior to the introduction of the interferometer, the compound microscope had to be used in connection with very delicate measurements of length. The microscope, however, could not be used for objects smaller than one-half a wave length of light. Two physicists (Professors Michelson and Morley) developed an instrument which was named the *interferometer*, for accomplishing in the laboratory what was beyond the range of the compound microscope. This instrument consisted principally of a system of optical mirrors arranged in such a way as to let the waves of light from a suitable source pass between and through them, the waves in the course of their travel being divided and reflected a certain number of times, thus making it possible to measure objects ten times smaller than was possible with the best compound microscope obtainable. Professor C. W. Chamberlain of Denison University invented another instrument known as the *compound interferometer* which is much more sensitive than the one previously referred to; in fact, it is claimed that it will measure a distance as small as one twenty-millionth of an inch. These compound interferometers have been constructed in several different forms.

An important practical application of the interferometer is in measuring precision gages by a fundamental method of measurement. The use of this optical apparatus is a scientific undertaking, requiring considerable time and involving complex calculations. For this reason all commercial methods of checking accuracy must be comparative, and the taking of fundamental measurements is necessarily confined to the basic or primary standards, such as are used to a very limited extent for checking working masters, where

the greatest possible degree of accuracy is required. The interferometer is used to assist in determining the number of light waves of known wave length (or color) which at a given instant are between two planes coinciding with the opposite faces of a gage-block or whatever part is to be measured. When this number is known, the thickness can be computed because the lengths of the light waves used have been determined with almost absolute precision. The light, therefore, becomes a scale with divisions — approximately two hundred-thousandths inch apart.

INTERLOCKING SAFETY DEVICE. An interlocking safety device is any means for the protection of workmen against accidents due to the operation of machinery, which is so arranged that it is made mechanically impossible for the operator to set a machine in motion while his hand or fingers, or other parts of his body, are in a dangerous position. In a press for example, it may be necessary to grip two levers, one with each hand, in order to throw the clutch and make the machine operate; in pneumatic devices, two valves may have to be opened, one with each hand; in electric operation, the pressure of two buttons to complete the circuit may be required.

INTERMITTENT GEARING. Intermittent gearing is so designed that the driving gear imparts an intermittent motion to the driven gear, instead of driving it continuously. In many kinds of mechanism, this intermittent motion between a driving and a driven member is required. By using different forms of intermittent gears, the motion may be varied considerably. Some intermittent gearing is so arranged that each revolution of the driver moves the driven gear through part of a revolution, there being several periods of rest for the driven member before it is turned completely around or through one revolution. With other forms of intermittent gearing, the driven gear has only one period of rest for each revolution of the driver; the arrangement may also be such that there are several variable rest periods. Gears of the intermittent type are made in many different designs which are modified to suit the conditions governing their operation, such as the necessity for accurately locking the driven member while idle, speed of rotation, and the inertia of the part connected to the driven gear.

INTERNAL COMBUSTION ENGINES. Gas and oil engines, generally grouped together under the name *internal combustion engines*, are machines for the transformation of heat into work. They differ from other types of heat engines in that the fuel is burned within the cylinder or working chamber of the engine, and the products of combustion constitute the working fluid. Internal combustion engines may use a gas, an easily vaporizable liquid, such as gasoline, or a liquid which is difficult to vaporize, such as fuel oil. Engines using gas as fuel are termed *gas engines;* those using gasoline are

termed *gasoline engines;* and those using heavy oils are termed *oil engines.* Since the working fluid of all these engines is a highly heated gas, they are all frequently termed "gas engines," instead of using the longer, but more correct, name of "internal combustion engines."

Four-stroke Cycle. — During the first stroke of a four-stroke cycle engine, the inlet valve remains open, and the exhaust valve remains closed. The piston is drawn forward by the revolution of the crank, and an intimate mixture of air and fuel or "charge" is drawn into the cylinder; hence, the first stroke of the cycle is called the *suction stroke.* At the end of the suction stroke, the inlet valve closes. As the crank continues to revolve, the piston is pushed back, and since both the inlet and exhaust valves are closed, the charge is compressed into the clearance space. Accordingly, the second stroke of the cycle is called the *compression stroke.* During this stroke, not only does the volume of the charge diminish and its pressure increase, but its temperature also increases, since the temperature of a gas always rises when it is compressed, unless special means are taken during the compression to cool the gas, and so remove the heat which is created in it by the work of compression.

While the engine is on or near the dead-center at the end of the compression stroke, the charge is ignited by an electric spark. The fuel is instantly burned, and a considerable quantity of heat generated. As a result the temperature of the charge is instantly raised, until it reaches a value of between 3000 and 4000 degrees F. This rise in temperature produces a corresponding rise in pressure, which is termed the *explosion.* Immediately after the ignition, the pressure of the charge reaches a value of from 250 to 700 pounds per square inch. After the explosion, the crank continuing to revolve, the piston again moves forward, both valves remaining closed. This is the power producing stroke. The charge expands in volume, forcing the piston forward. In consequence, this stroke of the cycle is called the *expansion stroke.* The work done by the expanding charge upon the piston is largely expended in accelerating the flywheel, which acts as a reservoir of energy. At the end of the expansion stroke, the exhaust valve opens, and the pressure of the charge falls to that of the atmosphere. The revolving crank forces the piston back, and the burned charge is expelled from the cylinder, during the fourth stroke, termed the *exhaust stroke,* and the cycle is complete. It will be noted that the cycle requires four strokes or two full revolutions of the crankshaft.

Two-stroke Cycle. — In a two-stroke cycle engine the piston acts as both an inlet and exhaust valve. Assume that the cylinder is filled with a mixture of air and fuel. The crank revolves, the piston rises, and the charge is compressed. When the piston is at or near its highest point, the charge is ignited, and the piston descends. During its upward stroke, the piston

draws into the crankcase (which is an air-tight casting containing the crank and connecting-rod) a fresh quantity of charge, through the check-valve. During its downward stroke, the piston compresses this charge. When the piston approaches the bottom of its stroke, its motion uncovers an exhaust port, so that the burned charge escapes, and the pressure falls. An instant later the motion uncovers an inlet port, and the fresh charge forces its way in from the crankcase, driving the remainder of the burned charge before it. A projection on the top of the piston is for the purpose of deflecting the fresh charge, and preventing it from passing directly across the cylinder, and out at the exhaust. Engines of this type, using gasoline for fuel, are frequently employed for marine and stationary service whereas the four-stroke cycle engines are used on motor cars, airplanes, and for various other purposes.

INTERNAL COMBUSTION RIVETER. The internal combustion riveter depends upon the explosion of a charge of some fuel such as gas or any of the liquid fuels common in gas-engine practice. There is a cylinder containing a piston which is connected by means of the ordinary toggle mechanism direct to the head die. A small electric motor is mounted on the cylinder, and the armature is connected directly to a carbureting pump. When a rivet is to be set, a lever is thrown in one direction, thereby closing the motor switch and starting the motor, so that a carbureted charge is pumped into the cylinder. This charge impels the piston forward for about one-fourth of its working stroke, causing the head die to descend. As soon as the die is in contact with the rivet, the motion of the piston is arrested, which causes the pressure in the cylinder to rise, and then a small automatic plunger cuts out the motor switch and, at the same time, operates an igniter, thus exploding the charge in the cylinder. As the result of this explosion, the piston is forced to the end of its working stroke, thus setting the rivet. The operator then reverses the lever, thus opening an exhaust valve and exhausting the burnt gases from the cylinder; the piston then returns to its original position. This return movement is effected automatically by means of a coiled spring. The pressure may readily be varied by the adjustment of a small lever which increases or decreases the volume of the charge admitted to the cylinder.

INTERNAL EXPANDING CLUTCH. This is a friction clutch provided with shoes which are forced outward against an enclosing drum by the action of levers connecting with a collar free to slide along the shaft. The engaging shoes are usually lined with wood.

INTERNAL GEARS. An internal spur gear has teeth formed on an interior surface instead of on an exterior one as in the case of an ordinary spur gear. Briefly, and perhaps somewhat unconventionally defined, it is an ordinary spur gear turned inside out. There are some advantages incident

to the use of internal gears for particular applications, as compared with external gears of the same pitch and number of teeth. An internal gear has its teeth and those of its pinion protected to a very marked degree from inflicting or receiving injury, often making the use of a gear guard unnecessary, if the parts are properly designed in this respect. Owing to the fact that the cylindrical pitch surfaces in internal gearing have their curvature in the same direction, the teeth of the pinion approach and mesh with those of its mate somewhat more gradually and easily than when they are meshing with an external gear. This tends toward smoothness and quietness in running, as well as giving a slightly longer contact for each tooth. Internal gears of the same pitch and number of teeth, have a much smaller center distance than external gears, which is often an advantage.

Cutting Methods. — Internal spur gears are usually cut by one of the following methods: (1) By using a formed cutter and milling the teeth; (2) by a molding-generating process, as when using a Fellows gear shaper; (3) by planing, using a machine of the templet or form-copying type (especially applicable to gears of large pitch); and (4) by using a formed tool which reproduces its shape and is given a planing action either on a slotting or a planing type of machine. The machines used ordinarily for cutting internal gears are designs intended primarily for external gears. These machines may be arranged for internal gear-cutting by using some form of attachment which provides means of holding the cutter in the position required for forming gear teeth around an inner surface.

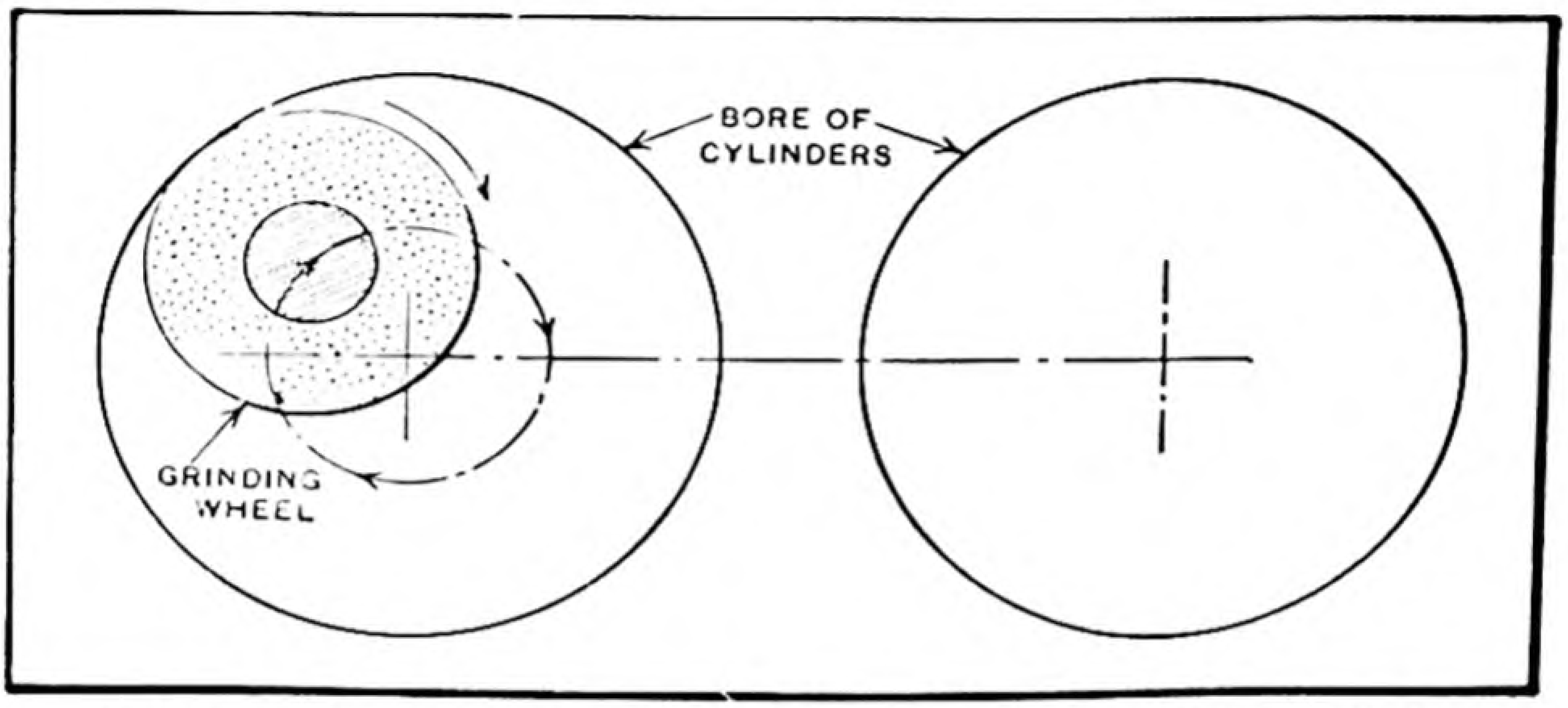
Internal Bevel Gear. — The pinion cone of an internal bevel gear, rolls on the interior surface of a concave gear cone, while in the more common type of bevel gearing, the pinion cone rolls upon the exterior surface of a convex gear cone; hence the pitch cone angle of an internal gear is greater than 90 degrees.

INTERNAL GEARS, WILLIAMS. In the Williams system, the profiles of the internal gear teeth are straight lines, so that the tooth spaces are similar to those of an involute rack, while the teeth of the mating pinion have curved profiles of conjugate form. This gearing is designed to secure a much longer arc of tooth contact, improved operating action, reduced wear, and increased strength of the pinion teeth.

INTERNAL GRINDING MACHINES. On one type of internal grinding machine the work head is stationary and the wheel-spindle is traversed. The wheel-spindle of another type is supported by a stationary portion of the frame, and the work head is mounted on the table of the machine and travels to and from the grinding wheel. The former type is used to a large extent in machines especially designed for internal grinding. Some machines, instead of being designed for internal grinding exclusively, are

combination types which will grind both internal and external diameters on the work at the same chucking. In the design of internal grinders much attention has been given to the spindle and its mounting in order to obtain the high-speeds essential to efficient grinding.

For grinding cylinders, a special type of internal grinding machine has been developed in which the work does not have to be rotated, as is the case with the ordinary type of internal grinding machines. The grinding wheel



Action of Planetary or Eccentric-head Type of Cylinder Grinder

not only rotates about its own axis but has a circular or planetary movement (as indicated by the diagram) so that it follows around the walls of the hole being ground as the work is fed in a lengthwise direction.

INTERNAL GRINDING MACHINE, SIZE-INDICATING. One type of internal grinding machine designed particularly for high production on duplicate work is equipped with a dial type of size-indicating device, and automatic control for various important movements. After the work is chucked and the machine started, the wheel-head advances rapidly to the work, and then automatically slows down to the rate of travel required for grinding. The wheel grinds on the far side of the hole so that the operator has a clear view.

With the coarse feed, the wheel roughs the hole to approximately the finish size as shown by the indicator; then the operator lifts a latch controlling a dog that short-strokes the table just enough to allow the wheel-truing diamond to drop into place, truing the wheel as it re-enters the hole. This provides a true, sharp wheel, which together with an automatic change to fine feed is suitable for the finishing cuts. Upon reaching finish size, the operator steps on a treadle, and the wheel-head withdraws at full speed to the rest position. The work and water automatically stop, and the wheel is automatically guarded.

The sizing control unit has a diamond pointed finger which is in contact with the hole in the work at all times when grinding, but which automatically

swings out of the way as the table withdraws to the rest position, allowing for quick removal and chucking of the work. The position of this sizing unit can be adjusted for various sizes of holes. It can be swung out of the way also, when the operator desires to true up a new wheel or grind a " master hole."

INTERNALLY-FIRED FURNACES. The heating chamber and the combustion chamber of some furnaces are combined. This arrangement is applicable to forge furnaces, rod and rivet heaters, etc., in which an intense heat is required, and the work will not be seriously affected by the direct action of the flame. Melting furnaces of some types are also internally fired. It is but rarely desirable to have the flame proper strike directly against the cold work, as combustion is thereby retarded and soot is often deposited on the work, particularly when oil fuel is used. This type is largely confined to the use of gas and oil fuel. The common pit type of crucible melting furnace, using coke or hard coal, is a notable exception

INTERNAL STRESSES. Castings are sometimes sprung out of shape by the internal stresses existing in the casting itself. These stresses are caused by the unequal cooling of the casting in the foundry. When a casting is made, the molten metal which comes in contact with the walls of the mold naturally cools first and, in cooling, contracts and becomes solid while the interior is still more or less molten. The result is that when the interior cools and contracts, the tendency is to distort the part which solidified first, and internal stresses are left in the casting.

INTERNATIONAL ATOMIC WEIGHTS. These are atomic weights which are based upon the value of the atomic weight of oxygen as 16.

INTERNATIONAL SCREW THREAD. The international standard screw thread is of the same form as the United States standard thread, but the pitches are given in millimeters and are somewhat finer for corresponding diameters than in the United States standard thread system. This system was adopted by an international congress for the standardization of screw threads, held in Zürich, Switzerland, 1898.

INTERNATIONAL VOLT. See Volt.

INTERPOLATION. In mathematics, interpolation is the process of finding a value in a table or in a mathematical expression which falls between two given tabulated or known values. In engineering handbooks, the values of trigonometric functions are usually given to degrees and minutes; hence if the given angle is to degrees, minutes and seconds, the value of the function is determined from the nearest given values, by interpolation.

Interpolation to Find Functions of an Angle. — Assume that the sine of $14° 22' 26''$ is to be determined. It is evident that this value lies between

the sine of 14° 22′ and the sine of 14° 23′. Sine 14° 23′ = 0.24841 and sine 14° 22′ = 0.24813. The difference = 0.24841 − 0.24813 = 0.00028. Consider this difference as a whole number (28) and multiply it by a fraction having as its numerator the number of seconds (26) in the given angle, and as its denominator 60 (number of seconds in one minute). Thus $\frac{26}{60} \times 28 =$ 12 nearly; hence, by adding 0.00012 to sine of 14° 22′ we find that sine 14° 22′ 26″ = 0.24813 + 0.00012 = 0.24825. The correction value (represented in this example by 0.00012) is *added* to the function of the *smaller* angle nearest the given angle in dealing with *sines* or *tangents* but this correction value is *subtracted* in dealing with cosines or cotangents.

Interpolation to Find Angle.—Example: Find the angle whose cosine is 0.27052. A table of trigonometric functions shows that the desired angle is between 74° 18′ and 74° 19′ because the cosines of these angles are, respectively, 0.27060 and 0.27032. The difference = 0.27060 − 0.27032 = 0.00028. From the cosine of the *smaller* angle or 0.27060, subtract the given cosine; thus 0.27060 − 0.27052 = 0.00008; hence $\frac{8}{28} \times 60 = 17''$ or the number of seconds to add to the smaller angle to obtain the required angle. Thus the angle whose cosine is 0.27052 = 74° 18′ 17″. Angles corresponding to given sines, tangents, or cotangents may be determined by the same method.

INVAR. Invar is a nickel steel containing about 36 per cent nickel, together with about 0.5 per cent each of carbon and manganese, with metallurgically negligible quantities of sulphur, phosphorus, and other elements, the remainder being iron. It is made either in the open-hearth furnace or by the crucible method. It melts at about 1425 degrees C. (about 2600 degrees F.). The value of this alloy lies in the fact that it has a very small coefficient of expansion due to heat, and it is, therefore, used in scientific instruments, for standard length measurements, and in high-grade measuring tapes. It may also be used in incandescent electric lamps for the wire connections which are fused into the glass. Invar can be forged, rolled, turned, filed, and drawn into wires; and it takes a beautiful polish. In general, it should be worked slowly. It will withstand the corrosive action of water without spotting, even when immersed for several days. Its specific gravity is about 8; its electrical resistivity is about 8 times that of pure iron; and its temperature coefficient of electrical resistance about 0.0012 per degree C. It is ferro-magnetic, but becomes paramagnetic in the neighborhood of 165 degrees C. (about 330 degrees F.). The mechanical properties are about as follows: Tensile strength, 50,000 to 85,000 pounds per square inch; elastic limit, 7000 to 30,000 pounds per square inch; elongation, 40 to 50 per cent; reduction of area, 40 to 65 per cent; scleroscope hardness, 19; and Brinell hardness, 160.

INVENTION, WHAT CONSTITUTES. See Patents.

INVENTORS, JOINT. See Joint Inventors.

INVERTED SYNCHRONOUS CONVERTER. This is a rotating electrical machine used for converting direct current into alternating current; see Synchronous Converter.

INVERTED-TOOTH CHAIN. This is a driving chain for power transmission having projections or teeth that engage the sprocket in a manner similar to that in which a rack engages a gear. It is the same as Silent Chain.

INVERTED TYPE ACCUMULATOR. A hydraulic accumulator in which the cylinder, fitting over the plunger from above, supports the weights necessary to produce the required pressure, is known as an inverted type accumulator.

INVOLUTE. If a circular disk were placed upon a drawing-board, an involute curve would be described by the end of a taut line if the latter were unwound from this disk, in the plane of the board. The disk represents in gear design, what is known as the *base circle*, because it is from this circle that the involute tooth curves are derived.

INVOLUTE GEAR TEETH. The involute curve is made use of in forming the teeth of the involute system of gearing, which is the system used for practically all cut-gear teeth. The involute gear-tooth system has the advantage over the cycloidal tooth system in that gears with involute teeth will run correctly even if the distance between the centers of the gears is not theoretically correct. The relative velocities of two gears having involute teeth will be the same even if their center distance is altered. The unmodified involute rack tooth has straight sides, but in practice the points may be slightly rounded off to avoid interference. The basic rack of the American standard spur gear tooth form has cycloidal curves above and below a straight mid-section. See Gear Tooth Standardization.

Interchangeable Involute Gears. — An interchangeable system of involute gearing comprises all gears which can be generated by a particular involute rack. All of these gears will be interchangeable, and will not only mesh correctly with each other, but, under certain conditions, will also be able to generate each other. Thus, if we have only one gear of the system, we can reproduce the others by a purely generating action. The generating rack must satisfy the conditions that the thickness of the tooth must be equal to the width of space, the working depths above and below the pitch-line must be the same, and finally the tooth must be symmetrical.

All involute spur and helical (spiral) gears which have the same normal pitch, normal pressure angle, and working depth are interchangeable, and

will generate each other. They will generate on each other correctly that part of the tooth surface which extends from the base cylinder to the outside cylinder, that is, the whole contact surface of the tooth, while the portion of the tooth surface which lies below the base cylinder will be completely generated only by the rack. In the case of any other member of the system being used for generating, for example, a pinion, as on the gear shaper, the portion of the surface below the base cylinder will only be incompletely generated. This difficulty can best be overcome by increasing the depth of teeth below the pitch-line in order to provide sufficient clearance for any gear of the system.

IODINE NUMBER. Iodine value or number is the number of milligrams of iodine that one gram of a fat or oil will absorb under specific conditions, and for fixed oils the iodine value is usually fairly constant, marked variation indicating adulteration.

IONS. In electrochemistry, molecules are supposed to be composed of *ions* which may or may not be identical with the chemical atoms, and are thought to be highly charged with positive or negative electricity. For example, the action of a weak electric current on a solution of hydrochloric acid *dissociates* the acid into its ions of hydrogen and chlorine, which are identical with its atoms; but one ion of chloric acid consists of an atom of hydrogen, while the other ion consists of one atom of chlorine and three atoms of oxygen.

IRIDIO-PLATINUM. Iridio-platinum is an alloy of iridium and platinum, containing about 10 per cent of iridium and 90 per cent of platinum. The alloy is used for international weight standards, electrodes exposed to acid liquids, and wires forming part of high-temperature pyrometers. It is a remarkably hard alloy, susceptible of high polish. Very few chemical reagents attack it.

IRIDIUM. Iridium is one of the metallic chemical elements of the platinum group, its symbol being Ir, and its atomic weight, 193.1. It is a metal of silvery-white color and is always present in platinum ores in the form of alloys of platinum and iridium and of osmium and iridium. It is a brittle, hard metal and is one of the heaviest substances known, its specific gravity being 22.42, which is equivalent to a weight per cubic inch of 0.809 pound. Iridium is fusible only with great difficulty, its melting point being at 2300 degrees C. (about 4170 degrees F.). Practically all commercial platinum contains iridium. It is used for the points of gold pens in fountain-pen manufacture, and is also alloyed with platinum to act as a hardener for this metal. Very little pure platinum is now being used, nearly all the commercial metal passing under this name being so-called "hard platinum," which is an alloy of platinum and iridium.

IRIDOSMIUM. Iridosmium is an alloy of the metals iridium and osmium, which is found in nature in different proportions. The alloy has a specific gravity varying from 19.3 to 21, and a hardness almost equal to that of quartz. The color resembles that of tin or steel. The alloy usually contains small percentages of rhodium, ruthenium, and platinum. It is found in connection with platinum ores in the Ural Mountains and in Northern California. The alloy is used for the points of gold pens.

IRON. The term "iron," as used in the chemical or scientific sense of the word, refers to the chemical element iron or pure iron, which is the chief constituent in all commercial iron and steel. As applied to the commercial product, however, the term "iron" is most generally used to indicate wrought iron, as distinguished from steel or cast iron. Pure iron is not used in the industries, but all the commercial products containing iron as the chief element — wrought iron, cast iron, steel castings, Bessemer steel, open-hearth steel, crucible steel, alloy steel, etc., — contain also small percentages of carbon and a number of other elements, the presence of which determine the characteristics of each class of commercial iron and steel. Iron is found in nature in the form of iron ore, and all the irons and steels used in the industries are produced from iron ore by a number of different processes.

Pure iron is silvery white, tenacious, malleable, ductile, and has a high melting point. The chemical symbol of iron is Fe, its atomic weight is 55.84, and its specific gravity, 7.84, giving a weight per cubic inch of 0.283 pound. Its linear expansion per unit length in degrees F. is 0.0000065, and its average specific heat for temperatures between 60 and 212 degrees F., 0.11; this value of the specific heat increases with the temperature, up to about 1550 degrees F., and then diminishes. The melting point of pure iron is given by the Bureau of Standards as 1520 degrees C. (2768 degrees F.).

IRON, ACID-RESISTING. See Duriron.

IRON AND STEEL DEFINITIONS. At the Brussels Congress of the International Association for Testing Materials held in September, 1906, the following definitions of the most important forms of iron and steel were adopted:

Alloy Cast Irons. — Irons which owe their properties chiefly to the presence of an element other than carbon.

Alloy Steels. — Steels which owe their properties chiefly to the presence of an element other than carbon.

Basic Pig Iron. — Pig iron containing so little silicon and sulphur that it is suited for easy conversion into steel by the basic open-hearth process (restricted to pig iron containing not more than 1.00 per cent of silicon).

Bessemer Pig Iron. — Iron which contains so little phosphorus and sulphur that it can be used for conversion into steel by the original or acid

Bessemer process (restricted to pig iron containing not more than 0.10 per cent of phosphorus).

Bessemer Steel. — Steel made by the Bessemer process, irrespective of carbon content.

Blister Steel. — Steel made by carburizing wrought iron by heating it in contact with carbonaceous matter.

Cast Iron. — Iron containing so much carbon or its equivalent that it is not malleable at any temperature. The committee recommends drawing the line between cast iron and steel at 2.20 per cent carbon.

Cast Steel. — The same as crucible steel; obsolete, and confusing; the terms " crucible steel " or " tool steel " are to be preferred.

Charcoal Hearth Cast Iron. — Cast iron which has had its silicon and usually its phosphorus removed in the charcoal hearth, but still contains so much carbon as to be distinctly cast iron.

Converted Steel. — The same as blister steel.

Crucible Steel. — Steel made by the crucible process, irrespective of its carbon content.

Gray Pig Iron and Gray Cast Iron. — Pig iron and cast iron in the fracture of which the iron itself is nearly or quite concealed by graphite, so that the fracture has the gray color of graphite.

Malleable Castings. — Castings made from iron which when first made is in the condition of cast iron, and is made malleable by subsequent treatment without fusion.

Malleable Iron. — The same as wrought iron.

Malleable Pig Iron. — An American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting.

Open-hearth Steel. — Steel made by the open-hearth process irrespective of its carbon content.

Pig Iron. — Cast iron which has been cast into pigs direct from the blast furnace.

Puddled Iron. — Wrought iron made by the puddling process.

Puddled Steel. — Steel made by the puddling process, and necessarily slag-bearing.

Refined Cast Iron. — Cast iron which has had most of its silicon removed in the refinery furnace, but still contains so much carbon as to be distinctly cast iron.

Shear Steel. — Steel, usually in the form of bars, made from blister steel by shearing it into short lengths, piling, and welding these by rolling or hammering them at a welding heat. If this process of shearing, etc., is repeated, the product is called " double-shear steel."

Steel. — Iron which is malleable at least in some one range of temperature and, in addition, is either (*a*) cast into an initially malleable mass; or, (*b*) is capable of hardening greatly by sudden cooling; or, (*c*) is both so cast and so capable of hardening.

Steel Castings. — Unforged and unrolled castings made of Bessemer, open-hearth, crucible, or any other steel.

Washed Metal. — Cast iron from which most of the silicon and phosphor have been removed by the Bell-Krupp process without removing much of the carbon, still contains enough carbon to be cast iron.

Weld Iron. — The same as wrought iron; obsolete and needless.

White Pig Iron and White Cast Iron. — Pig iron and cast iron in the fracture of which little or no graphite is visible, so that their fracture is silvery and white.

Wrought Iron. — Slag-bearing, malleable iron, which does not harden materially when suddenly cooled.

IRON FOUNDING IN AMERICA. Joseph Jenks, who came from England to Lynn, Mass., about 1642, is said to have been the first founder who worked in brass and iron on the Western continent. An iron quart pot is said to have been the first casting made. The iron foundry and forge was located near a bog-iron mine and had the backing of Gov. Winthrop. From this crude beginning the spread of iron manufacturing continued without a break up to the present time. Jenks built for the town of Boston, the first fire engine used in the United States, and also constructed machines for drawing wire.

IRON IN IRON ORE. Iron ore contains ordinarily from 35 to 65 per cent of iron, and, in addition, oxygen, phosphorus, sulphur, silica (sand), and other impurities. If the ore contains less than 40 per cent of iron, it must first be concentrated, and, if less than 25 per cent of iron, it is not considered a commercial product, owing to the excessive cost of smelting. The ores mined in the United States average slightly over 50 per cent of iron, although the "Lake" ores sometimes contain over 60 per cent. Iron ores which consist of carbonates — minerals in which iron is present with oxygen and carbon — and sulphides — minerals in which the iron is present with sulphur — are also used, but these ores must be roasted to drive off the carbonic acid of the carbonate ore and reduce the sulphur in the sulphide ore. Iron ore in which sulphur is present to an amount exceeding 1 per cent must always be treated in this manner. Magnetite is an ore that has derived its name from the fact that it is attracted by the magnet. In magnetite ores, iron is present as a magnetic oxide, Fe_3O_4, which, when pure, contains 72.4 per cent of iron. See also Magnetite, and Hematite.

IRON ORE BENEFICIATION. The term " beneficiation " is applied to those processes used for the improvement of ores which result in producing an ore which contains a greater percentage of the metal to be extracted than the original mined product. It is also applied to those methods which change the physical and sometimes the chemical properties of the ore so that it will meet the requirements for a commercial product. In the past, the term " beneficiation " has been applied to ores of precious metals only, but at the present time it is also applied to the ores of other metals, such as iron.

IRON ORE GRADING. Iron ore is graded according to the percentage of phosphorus it contains. A low percentage of phosphorus — under $4\frac{1}{2}$ per cent — makes it available for the Bessemer steel-making process, and such ore is called Bessemer ore. The non-Bessemer ore, which contains a higher percentage of phosphorus, is made into steel by the basic open-hearth process, which admits of the elimination of the phosphorus.

ISINGLASS. This is a term commonly confused with mica, although it designates a totally different substance. The material is used in belt cements of the best grade. It is prepared from the air bladders of the Russian sturgeon, caught in the Baltic Sea. The isinglass from the Russian sturgeon is superior to that made from the American sturgeon.

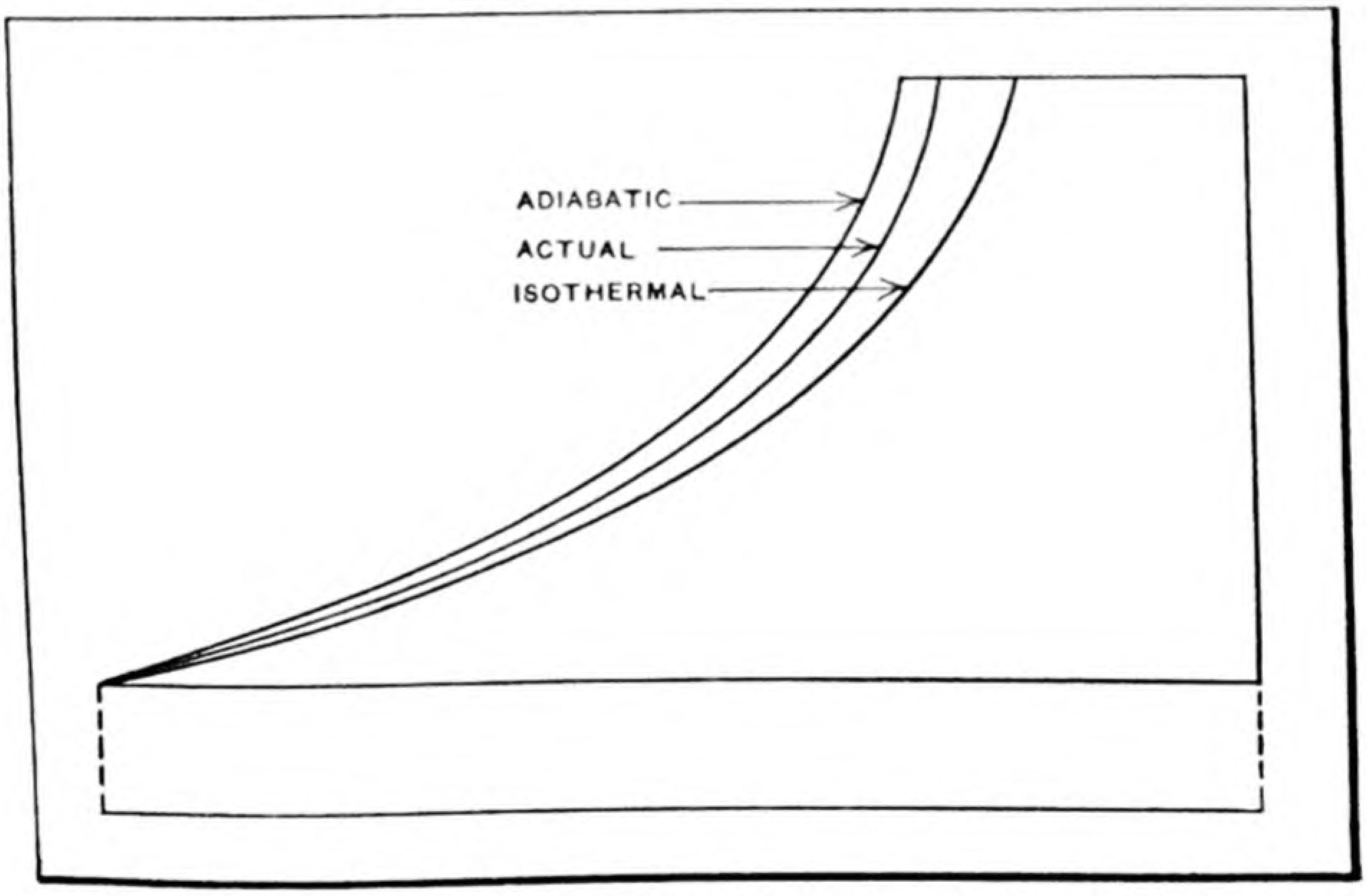
ISOLANTITE. Isolantite is the name of a material that is claimed to be harder than glass, but not brittle, having a toughness greater than cast iron, that it is capable of resisting incandescent heat followed by a plunge in cold water without damage, that it is practically moisture-proof, and that it can be produced in a soft state so that it can be machined into all kinds of shapes and sizes with great precision, and can have threads cut on it, after which it can be hardened to obtain the extreme properties mentioned. It is unaffected by commercial acids, alkalis, and solvents, and makes an effective electrical insulator. When in its soft state, it is turned, drilled, milled or threaded in the same manner as metal. The threads are said to be even stronger than metal threads, and machine screws screwed into threaded " Isolantite " are said to have been stripped of their threads before the threads in the " Isolantite " gave way. The material is pure white and smooth in its finished state.

ISOMETRIC PROJECTION. In ordinary mechanical drawing, the orthographic method of projection is used, the object being represented in two or more views in which all lines are drawn to the same scale. Another system of representing objects, known as " isometric projection " is used to show in one view the appearance and the dimensions of an object in all directions; that is, to show both length or height, breadth or width, and thickness. The isometric method of projection differs from perspective drawing in that it shows the object in its true dimensions, all lines in any

given direction being drawn to some given scale, and all lines that are parallel in the object being shown parallel in the drawing. The perspective drawing, on the other hand, shows the object as it would appear to the eye, the lines converging toward a common vanishing point.

ISOTHERMAL EXPANSION AND COMPRESSION. When a given volume of gas expands the temperature naturally decreases, assuming that heat is not supplied to compensate for the loss due to expansion. If the expanding gas has enough heat added to it to keep the temperature constant, the expansion is isothermal and a curve representing such expansion is sometimes called the expansion curve of constant temperature.

When air is compressed, heat is generated and the temperature rises. If this heat could be removed as fast as generated, so as to maintain a constant temperature during the process of compression, *isothermal* compression would be obtained. If it were possible to compress air without adding



Adiabatic, Actual, and Isothermal Curves of Compression

to or removing the heat generated by the process of compression, *adiabatic* compression would be obtained. In the actual compression of air under practical working conditions, neither of these results are obtained, the curve of compression lying between the two, somewhat as shown by the diagram. The isothermal curve is only approached in the case of slow-speed machines where the air is in contact with the water jackets for a longer period than usual. In the ordinary type of compressor, working under normal conditions, the curve lies nearer to the adiabatic, as indicated in the illustration, and for this reason practical computations in connection with the design of compressors are usually based on adiabatic compression.

JACKS. Lifting jacks are made in many different types and sizes, ranging from the small jacks used for leveling and supporting work on planers to the powerful hydraulic jacks capable of lifting a locomotive or even greater weights. The mechanism by means of which jacks are operated also varies greatly. One of the simplest types consists of a screw which is inserted in a suitable base. There are also the gear-and-rack and the lever-and-rack types, in addition to many different designs that are hydraulically operated. While the lifting capacity varies greatly, in general, screw-jacks and those belonging to the reduction gear-and-rack class are capable of lifting loads up to about twenty tons, whereas those operated by hydraulic power ordinarily vary in capacity from four or five tons up to about five hundred tons.

JACKS, HYDRAULIC. See Hydraulic Jacks.

JACOBY METAL. Jacoby metal is a tin-antimony-copper alloy having a composition similar to britannia metal. It is suitable to be used for plated ware. The composition is as follows: Tin, 85 per cent; antimony, 10 per cent; and copper, 5 per cent. It can also be used as a high-grade bearing metal.

JAMB COKE. Jamb coke also known as "soft coke" and "heating coke," is the coke that is obtained next to the back and front of the coke oven and around the oven doors when producing regular foundry and furnace coke.

JAM-NUT. A jam-nut is a secondary nut which is screwed down tightly (jammed) against the regular holding nut on a bolt, the object of the jam-nut being to keep the other nut from working loose, due to vibrations. Jam-nuts are also known as *check-nuts* or *lock-nuts*.

JAPANESE ALLOYS. Metal alloys used for Japanese art work are composed mainly of copper with a number of other metals. One analysis shows 94.5 per cent of copper; 3.7 per cent of gold; 1.5 per cent of silver; 0.1 per cent of lead; with small percentages of zinc and iron. Another alloy is composed of 67.3 per cent copper; 32 per cent of silver; and 0.5 per cent of lead; with small percentages of gold, zinc, and iron. Another easily fusible metal for casting in plaster-of-paris is composed of 91.4 per cent of copper; 5.7 per cent of tin; and 2.9 per cent of lead. The term "Japanese alloy," therefore, does not signify any one composition.

JAPANNING. Japanning is a process that consists of applying an opaque, usually black, varnish to the surface of the object to be japanned, and baking it on the surface by means of high temperature in a japanning oven. The art of japanning originated with the Japanese; hence, the

name. The Japanese made their varnish or liquor from the secretions of certain kinds of trees. These, upon being exposed to the air, assumed a deep, dark color, to which pulverized charcoal was then added. The varnish so made was applied to the surface of the object to be coated in several successive coats. Each coat of varnish was baked on the surface in the sun before the next coat was applied. After the final coat had been baked on, it was polished, thus producing a smooth, glossy surface. The modern methods of japanning are different in everything, except the principle, from the methods used by the Japanese. The japan varnish used at the present time in manufacturing processes is composed generally of asphaltum, gum, linseed oil, turpentine, benzine, and some coloring matter, such as charcoal or boneblack. Objects may be coated with japan for several purposes: (1) To protect them from corrosion (rusting or tarnishing); (2) to protect them against chemical action, decomposition, or decay; and (3) for decorative purposes.

There are four methods of applying japan in general use: Brushing, dipping, tumbling, and spraying. After being applied the japan is either air-dried or baked. Each particular kind of baking japan can be baked at different temperatures, but in so doing the baking time must be varied with the temperature. One particular kind of japan can be baked at varying temperatures and for varying lengths of time from 300 degrees F. for 5 hours to 500 degrees F. for three-quarters of an hour. An air-drying japan that will require 24 hours to dry at ordinary temperatures can be baked in 3 hours at 180 degrees F. with equally good, if not better, results.

So-called "baking japans" are used widely in finishing a large variety of metal work requiring a decorative finish which is cheap and durable. The japan film is much harder than an ordinary paint film, and will stand rougher handling and usage, a circumstance which gives them a marked advantage in many cases.

JARNO TAPER. The Jarno taper was originally proposed by Oscar J. Beale of the Brown & Sharpe Mfg. Co., Providence, R. I. No table is necessary for the Jarno taper socket, as this socket is based on such simple formulas that practically no calculations are required when the number of taper is known. The taper per foot of all Jarno taper sizes is 0.600 inch on the diameter. The diameter at the large end is as many eighths, the diameter at the small end is as many tenths, and the length as many half inches as are indicated by the number of the taper. For example, a No. 7 Jarno taper is $\frac{7}{8}$ inch in diameter at the large end; $\frac{7}{10}$, or 0.700 inch at the small end; and $\frac{7}{2}$, or $3\frac{1}{2}$ inches long. The Jarno taper is used on various machine tools, especially profiling machines and die-sinking machines.

JET CONDENSER. The jet condenser condenses the exhaust steam of a steam engine or turbine by mixing the condensing or cooling water directly with the steam. In one type the exhaust steam enters at the top of the condenser, meeting the injection or cooling water, which is drawn in by suction due to the partial vacuum, and is discharged in the form of a spray, resulting in complete condensation of the steam. A greater drop in pressure for a given amount of cooling water is obtained in a jet condenser than in a surface condenser. There are two forms of jet condensers, the *parallel-flow* and the *counter-current* type

JEWELERS' BORAX. Jewelers' borax, also known as octahedral borax, is a form of borax suitable for use as a flux in soldering or welding.

JIB CRANE. A jib crane consists of a post or pillar supported and pivoted at top and bottom, from which a horizontal arm or jib extends. The jib has a crab or trolley moving in a radial direction along it. Generally, the jib is supported by a strut placed in an inclined direction between the vertical post and the jib.

JIG-BORING MACHINE Machines designed expressly for jig boring or similar work are so arranged that the part to be bored and the boring spindle or spindles can be adjusted to accurately locate the holes at given center-to-center distances without preliminary measurements or laying out. One design of jig-boring machine has a single spindle adjustable on a cross-rail located above a horizontal work-table, which may be adjusted along its bed in a direction at right angles to the cross-rail. Another larger and more elaborate design has three spindles — one vertical and two horizontal — for boring the top of the jig and opposite sides. The vertical spindle may be adjusted along a cross-rail which, in turn, may be raised or lowered to suit the work. The horizontal spindles are carried by slides adjustable vertically along the cross-rail uprights. These lateral and vertical adjustments of the three spindles, in conjunction with the longitudinal movement of the work-table, make it possible to bore holes in any position within the limits of spindle and table travel. Measurements may be made with great accuracy by the means provided and there is an automatic compensating device to eliminate small residual errors in the screws for moving the table and spindles.

JIGS AND FIXTURES. Jigs and fixtures serve the purpose of holding and properly locating a piece of work while it is being machined; they are provided with necessary appliances for guiding, supporting, setting, and gaging the tools in such a manner that all the work produced in the same jig or fixture will be alike in all respects, even with the employment of unskilled labor. As a general rule, a jig is a special tool, which, while it

holds the work, or is held onto the work, also contains guides for the respective tools to be used; whereas a fixture is only holding the work while the cutting tools are performing the operation on the piece, without containing any special arrangements for guiding these tools. The fixture, therefore, must, itself, be securely held or fixed to the machine on which the operation is performed; hence, the name. A fixture, however, may sometimes be provided with a number of gages and stops, although it does not contain any special devices for the guiding of the tools. The definition given, in a general way, would, therefore, classify jigs as special tools used particularly in drilling and boring operations, while fixtures, in particular, would be those special tools used on milling machines, and, in some cases, on planers, shapers, and slotting machines. Special tools used on the lathe may be either of the nature of jigs or fixtures, and sometimes the special tool is actually a combination of both, in which case the expressions "drilling fixture," "boring fixture," etc., are suitable.

A drill jig in its simplest form is merely a plate containing holes located so as to conform to the positions required for the holes to be drilled. This jig is placed over the part to be drilled and the drill itself is fed down through the different holes. In many cases parts must be drilled on different sides, and frequently castings or forgings are very irregular in shape, so that a jig which is made somewhat in the form of a box and encloses the work is necessary, as it makes it possible to place the holes in the jig on all sides and also makes it comparatively easy to locate and securely clamp the part in the proper position for drilling. A jig of this type is known as a *box jig* and is used very extensively. The use of a jig eliminates laying out holes by hand and insures accurate and uniform work.

JIG AND FIXTURE STANDARDIZATION. The use of standardized parts in the design of jigs and fixtures is intended primarily to avoid unnecessary repetitions in the designing department and to reduce the cost of designing jigs and fixtures as well as the time required for making them. The number or variety of parts which may be standardized to advantage in connection with jig and fixture design varies in different plants, and depends in a general way upon the uniformity of the work. Where there is great diversity in shapes and sizes of the parts requiring jigs or fixtures, standardization is largely confined to such details as handles, bushings, stop-pins, adjusting screws, clamping straps, latches, eyebolts, binder levers, and certain other small parts of a minor nature. In connection with the standardization of parts either for jigs, fixtures, or gaging devices, it is advisable to utilize as far as possible all universally adopted standards and commercial parts, such as machine screws, cap-screws, washers, taper pins, or other parts which may be much cheaper to buy than to make in relatively small lots. In determining whether or not it will pay to standardize

the larger and more important details, such as plates, bases, indexing devices, clamping mechanisms, etc., the probable extent to which such parts or details can be utilized is naturally the factor to consider.

JOBBERS' REAMER. This style of reamer is similar to a hand reamer, but it is provided with a taper shank so that it may be used for machine reaming. The shank is nearly always a Morse standard taper. Jobbers' reamers are fluted with the same kind of fluting cutters as reamers generally. The clearance is usually ground flat.

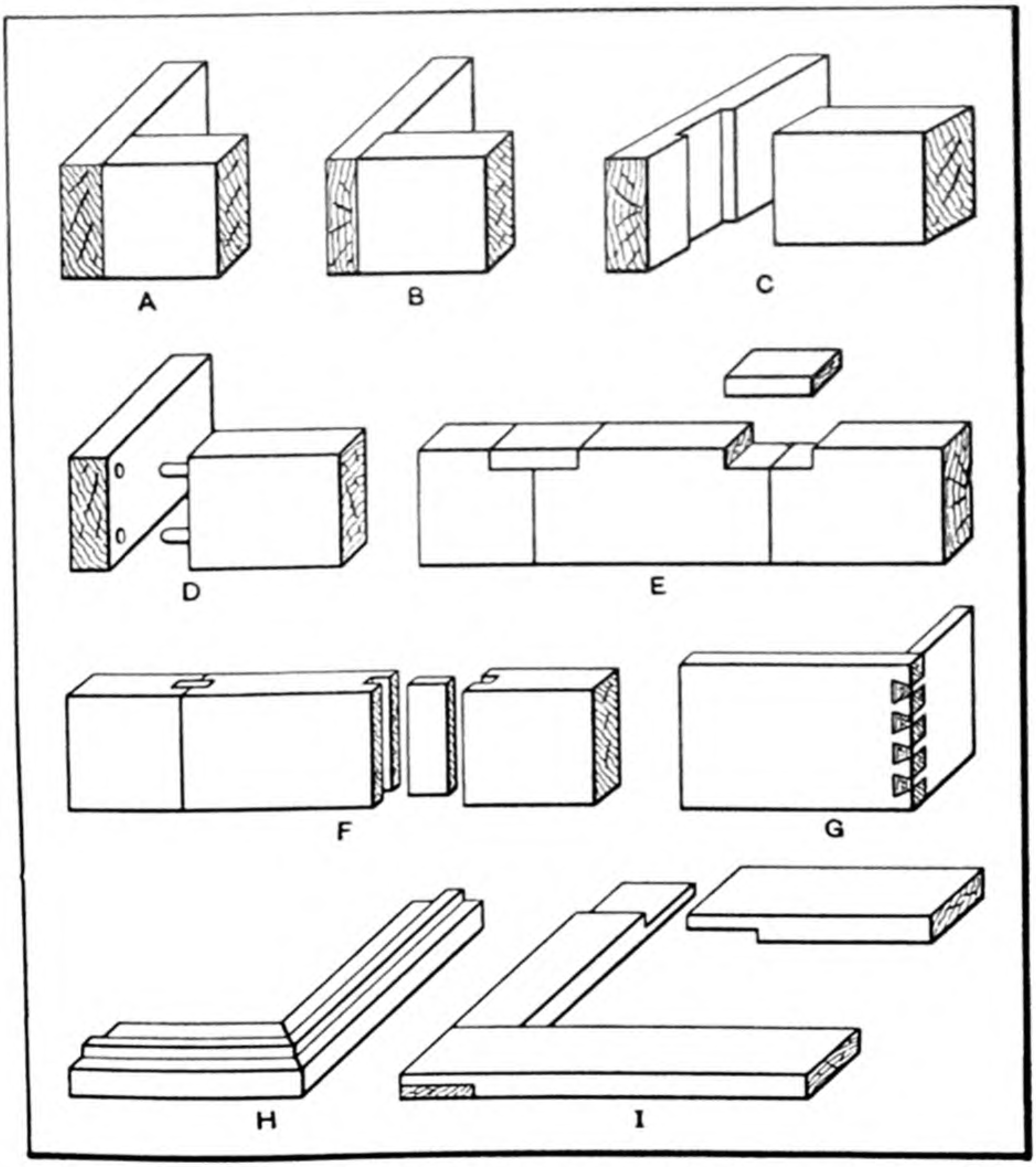
JOINTER. The "hand jointer," which is sometimes referred to as a "buzz planer," is used in wood-working shops for jointing and edging stock, the material being pushed by hand across the circular cutters that revolve at a high rate of speed. When in good condition and skillfully used, a plane surface or a straight edge is very easily produced.

JOINT INVENTORS. The term "joint inventors" is one that has been more or less misunderstood, not only by inventors, but also by others interested in patents. A person who furnishes capital only is in no sense a joint inventor, and his interest in the invention and the patent to be obtained therefor should be conveyed by an assignment executed in due form. To make clear the meaning of "joint inventors," suppose one inventor in collaboration with another, devises an engine for automobiles, both working on this particular part of the machine, and one making a suggestion here and the other there, a joint inventorship would exist. On the other hand, if one inventor were to design the motor, and his co-worker the transmission or the differential, there would not be a joint inventorship, for the reason that the motor could operate independently of the particular type of transmission employed, and the transmission could operate independently of the engine.

JOINT PATENTS. Where two or more persons work to perfect an invention, the application must be filed jointly, and the patent is issued in their names. And where two men work to perfect an invention, neither can apply for a patent as sole inventor and obtain a valid patent. Furthermore, the law is well established that where a patent is issued jointly to two or more inventors, either has the right to sell his interest, or manufacture and sell the invention, or license others to do so, without permission from the other inventor. Therefore, it is a good idea for joint applicants to enter into contractual relations whereby neither shall make the invention or license others to do so without permission of the other. If this is not done, and the patent is issued to two or more inventors, each of them has the same interest and rights in the patent as if only one were named as the patentee. Either one may proceed to market or license the invention without consulting the other, unless there is a contract to prevent it.

JOINTS USED IN PATTERNMAKING. The different forms of joints commonly used in the construction of patterns and in many other kinds of wood-working, are shown by the accompanying diagrams.

Butted Joint. — The butted joint *A* is the simplest form used in wood-working; two pieces are butted or placed one against the other and fastened with nails or screws, the latter giving a stronger joint.



Joints Used in Patternmaking

Rabbeted Joint. — The rabbeted joint is used in place of the butted joint when greater strength is required. The end of one piece is cut back or rabbeted, as shown at *B*, to receive the " butt " of the second piece.

Dado Joint. — The dado joint *C* is a standard for square and rectangular core-boxes. It prevents the ends from being rammed out or pushed in, and when it is fastened with screws, the box readily parts at the corners.

Doweled Joint. — The doweled joint *D* is a butted joint strengthened by dowel-pins.

Reinforced Butted Joint. — In making the reinforced butted joint *E*, a portion of each abutting section is cut away to receive a piece that covers the joint and prevents the sections from parting.

Splined or Feathered Joint. — The pieces to be joined are grooved to receive a spline or feather (as shown at *F*) which strengthens the joint. This form is used for fastening the arms of wheels and pulleys where they join at the center, and also to secure the joints of rings or flanges that are built of a single course of segments.

Dovetailed Joint. — This form of joint (which is shown at *G*) is used principally for holding the corners of beds and light boxes. The angle of the dovetails should be about $12\frac{1}{2}$ degrees.

Mitered Joint. — The mitered joint is used for connecting the corners of molding, etc. The angle for cutting is one-half the included angle of the connecting pieces. A 45-degree joint is shown at *H*.

Half-lapped Joint. — This joint is used for constructing framework; one-half of each piece is cut away as shown at *I*, so that, when the two sections are fastened together, they will be flush at the joints.

JOULE. The unit of work in electrical engineering, as recommended by the International Electrical Congress, in Chicago, 1893, and approved as a legal unit of electrical measure by an Act of Congress, July 12, 1894, is known as the *joule*, which is equal to the energy expended in one second by one ampere against the resistance of one ohm. One joule, expressed in mechanical equivalents, equals 0.74 foot-pound, or 0.000000278 kilowatt-hour. Commercially, this unit is too small and, therefore, either the watt-hour, which is 3600 times larger, or the kilowatt-hour, which is 3,600,000 times larger, is used.

JOURNAL. A journal is that part of a shaft or axle which is supported by and revolves in a bearing.

JOURNAL BRONZE. Journal bronze is an alloy composed mainly of copper, tin, and zinc. It contains, according to the U. S. Navy specifications, from 82 to 84 per cent of copper, from 12.5 to 14.5 per cent of tin, from 2.5 to 4.5 per cent of zinc, with a maximum of 0.06 per cent of iron and 1 per cent of lead. It is used for journal boxes, guide gibs of engines, bushings, etc.

JUMP TEST FOR GEARS. One of the commercial methods of testing gears is the so-called "jump test," which consists of placing the gears on a gear-testing machine, provided with suitable studs, one of which is mounted in a sliding part acted upon by a spring that tends to force the gears together. An indicator is affixed to the machine in such a manner that it will show the movement of the sliding part and stud when the gears are gently rolled

by hand, measuring the " jump " as each pair of teeth meshes. The maximum tolerance of jump in commercial gears should not exceed 0.010 inch divided by the diametral pitch of the gears. Dependence cannot be placed upon the jump test for gears that have backlash, because the thin teeth will not roll tightly at the proper center distance, and a closer center distance will not generally show the true condition.

JUNK VALUE. The junk value, also known as scrap value, in the appraisal of manufacturing plants, is the net price which can be obtained for the materials in a machine after deducting the expense of dismantling the machine and preparing the junk for shipment.

JUTE. Jute is a fiber obtained from the inner bark of certain trees growing in India, and is used to some extent as an electrical insulating material. For this purpose, it is usually softened and made less brittle by impregnating it with paraffin or some similar mineral oil. It is used extensively as a filler in lead-covered cables. The puncturing voltage for impregnated jute, for a thickness of about $\frac{1}{8}$ inch, is about 5000 volts; for a thickness of $\frac{1}{4}$ inch, about 7500 volts; for a thickness of $\frac{1}{2}$ inch, 12,000 volts; and for a thickness of 1 inch, 20,000 volts. When used as a filler between the insulated conductors of multiple-conductor cables, jute is placed directly in contact with the insulation. Tarred or asphalted jute is also used as a filler between the sheath and armor of armored cables.

KAHLE'S CELL. This is a primary cell or battery, known as a "standard" cell, used for obtaining a certain standard value of electromotive force under given conditions. In this cell, the positive electrode is amalgamated zinc, and the negative electrode, mercury. A paste of mercurous sulphate and zinc sulphate is placed upon the mercury and acts as a depolarizer. A saturated zinc sulphate solution acts as the electrolyte. The electromotive force of this cell is 1.43 volts at 15 degrees C. (59 degrees F.).

KARMARSCH METAL. A high-grade bearing metal of the tin-antimony-copper alloy group, containing 70.8 per cent of tin, 19.7 per cent of antimony, and 9.5 per cent of copper is known as Karmarsch metal. Another metal, known by the same name and used for the same purpose, is composed of 71.4 per cent of tin, 7.2 per cent of antimony, and 21.4 per cent of copper.

KEEP'S TEST. A method for testing the hardness of metals, which was introduced in 1887 by Keep, is known as "Keep's test." A standard steel drill is caused to make a definite number of revolutions while it is pressed with standard force against the metal specimen to be tested. The hardness is automatically recorded on a diagram on which a perfectly soft material gives a horizontal line and a material as hard as the drill itself, a vertical line. Intermediate degrees of hardness are represented by corresponding angles between 0 and 90 degrees. This hardness test is especially suitable for castings, as it records not merely the surface hardness, but also the hardness at any point throughout the thickness of the casting, and gives indications of blow-holes, hard streaks, and spongy places. It can be applied only to materials the hardness of which is less, and generally considerably less, than that of hardened steel.

KELVIN'S LAW. Kelvin's law relates to the most economical size of conductors for transmitting electric power. It is as follows: The most economical area of a conductor is that for which the annual interest on the capital outlay equals the annual cost on the energy loss in the conductors.

KENNEDY KEY. The Kennedy or double key system is used in rolling mills and is adapted to the transmission of heavy loads, especially where the torque is intermittent and the direction of rotation periodically reversed. Each key is so located that a diagonal line passing through two corners of the key approximately intersects the shaft axis. The keys have a taper of $\frac{1}{8}$ inch per foot on the hub side and the sides fit closely between the shaft and hub. The keys are driven in from opposite sides of the hub.

KEWANEE UNION. The Kewanee union is a patented pipe union having one pipe end of brass and the other of malleable iron, with a ring

or nut of malleable iron. The arrangement and finish of the several parts is such as to provide a non-corrosive ball-and-socket joint at the junction of the pipe ends, and a non-corrosive connection between the ring and brass pipe end.

KEY. A key of the type commonly used in machine construction consists ordinarily of a piece of steel, either square or rectangular in cross-section, which is inserted into a keyway or keyseat formed partly in a shaft and partly in the hub of a gear, pulley, or other part which, by means of the key, is driven positively and prevented from rotating relative to its shaft. While keys are used primarily to prevent relative rotation between shafts and such parts as pulleys, gears, etc., they also prevent axial movement in many cases, owing to the frictional resistance between the keyed parts. The type of key that may properly be employed in any case naturally depends somewhat upon the class of work for which it is intended.

The *sunk key* is the most common type. This is of rectangular section and engages a groove or slot formed both in the shaft and hub of the gear or pulley. The so-called *saddle key* does not enter a slot in the shaft, but is curved on the under side and is slightly tapered on top so that when driven into place the shaft is gripped by the frictional resistance. The *flat key* is a rectangular shape which bears upon a flat surface formed on one side of the shaft. The draw or *gib key* is a sunk key which has a head by means of which it can be removed. The *round tapered key* is simply a taper pin which is driven into a hole that is partly in the shaft and partly in the hub; this form is used for light work. The name *feather* or *spline* is applied to a key which is fixed to either a shaft or hub, as when a gear must be driven by a shaft, but at the same time be free to slide in a lengthwise direction. The *Woodruff key* is a section of a disk, the part which enters the shaft being circular.

The width of an ordinary sunk key ordinarily is equal to about one fourth of the shaft diameter and the thickness, when a flat key is preferred to the square form, is usually about one sixth of the shaft diameter; these proportions are varied somewhat by different manufacturers. The taper of American standard square and flat keys is $\frac{1}{8}$ inch per foot.

KEYSEATING MACHINES. The machines which are designed especially for cutting keyseats or keyways in the hubs of pulleys, gears, etc., are generally known as *keyseaters*. Machines of this class usually have a base or frame which contains mechanism for imparting a reciprocating motion to a cutter bar, which moves vertically for cutting a keyseat in the work. There are several types of machines which are used for internal keyseating operations in addition to the machines designed especially for

this work. Broaching machines as well as slotters are commonly used, and keyseating is also done to some extent in shapers and planers.

KILOGRAM-CALORIE. A kilogram-calorie, frequently simply termed "calorie," is a thermal unit based on the metric system, designating the amount of heat required for raising the temperature of one kilogram of pure water one degree C. One kilogram-calorie = 3.968 British thermal units = 1000 gram calories.

KILOGRAM-METER. This is a unit of work in the metric system, designating the work done in raising one kilogram to a height of one meter. One kilogram-meter = 7.233 foot-pounds.

KILOGRAM PER SQUARE CENTIMETER. This is a unit in the metric system for measuring pressure. One kilogram per square centimeter = 14.223 pounds per square inch.

KILOGRAM PER SQUARE MILLIMETER. This is a unit in the metric system for measuring pressure. One kilogram per square millimeter = 1422.32 pounds per square inch.

KILOVOLT-AMPERE. The term "kilovolt-ampere" (KVA.), equal to 1000 volt-amperes, expresses the *apparent* power in a circuit, *i.e.*, the product of the effective values of the current and the voltage, IE, in a reactive circuit. The term "kilowatt" (KW.), equal to 1000 watts, on the other hand, expresses the *true* power, $IE \times \cos\theta$, and is the reading obtained by a wattmeter applied to the circuit. The ratio of the watts to the volt-amperes is called the *power factor*. For example, assume an alternating-current generator supplying a load of 800 kilowatts, the power factor of which is 80 per cent. The true rating of such a generator, or the one on which the capacity of the prime mover should be based, would be 800 kilowatts, while the apparent rating of the generator would be $\frac{800}{0.80} = 1000$ kilovolt-amperes. To avoid any misunderstanding, the rating usually appears as follows: 1000 KVA. (800 KW., 0.8 power factor). For direct-current generators, however, the rating is always given in kilowatts, because these machines always operate on non-inductive load. The rating of a synchronous machine is usually determined by its permissible temperature rise caused by the current. This rise increases with increasing load and with decreasing power factor. Thus for a given kilovolt-ampere output, the total heat losses are larger for low than for high power factors, the difference being due to the heat generated by the increased field current which is required to overcome the armature reaction and maintain the given current and terminal voltage.

KILOWATT. The unit of power generally adopted for all electrical work and also frequently used in mechanical engineering is known as the "kilowatt." One kilowatt equals 1.34 horsepower, or one horsepower equals 0.746 kilowatt. The latter figure is the exact standard relationship between the kilowatt and the horsepower used by the United States Bureau of Standards, and may, therefore, be assumed as the exact equivalent of horsepower in electrical units. An effort has been made in scientific and engineering circles to substitute the kilowatt for the indefinite horsepower as the unit measurement of power. The kilowatt is just as good a mechanical unit as an electrical one, and it has the advantage of being a logical rating expressing a definite relation to the absolute system of measurements in general use for scientific purposes. One of the advantages of the kilowatt is that it is an absolute international unit which is not true of the horsepower. The latter, in countries using the metric system, is calculated as the equivalent of 75 kilogram-meters per second, which equals 542.5 foot-pounds per second, or 32,550 foot-pounds per minute — an appreciable amount less than the 33,000 foot-pounds constituting the British and American horsepower. The adoption of the kilowatt as a unit of power would avoid having generators rated in kilowatts while their driving machinery and electric motors are rated in horsepower.

KINETIC ENERGY. Energy, in mechanics, is defined as the capacity of a body for performing work and is measured in foot-pounds. It may be either *potential*, as in the case of a body of water stored in a reservoir, which is capable of doing work by means of a water turbine if released, or *kinetic*, which is the energy of a moving body. The kinetic energy of a moving body is the work which the body is capable of performing against a resistance before it is brought to rest. The kinetic energy of any moving body is equal to the work which has brought it from its state of rest to its actual velocity. The measure of the kinetic energy is the product of the weight of the body multiplied by the height from which it must fall to acquire its actual velocity; hence, if V = velocity in feet per second; W = weight of the body; g = acceleration due to gravity = 32.2: then, the kinetic energy E, in foot-pounds, equals:

$$E = \frac{WV^2}{2g}.$$

In a rotating body, the kinetic energy may be found by the same formula, if V is the velocity of the center of gyration.

KINITE. Kinite is the trade name for an alloy steel containing chromium and cobalt, but no tungsten, and has been found especially adapted for making dies requiring great resistance to abrasion or wear. Trimming

dies for hot forgings, for example, are among the tools for which the material is well suited. Furthermore, the material is practically non-corrosive, and has been found excellent for the making of glass and other molds requiring a high heat-resisting material.

KIRCHHOFF'S LAWS. Kirchhoff's first law is as follows: In any closed circuit, the algebraic sum of the electromotive forces, in volts, will be equal to the algebraic sums of the currents in the conductors multiplied respectively by the resistances of the conductors through which they flow. In other words, all the electric forces in the circuit are balanced. Kirchhoff's second law is as follows: If any number of wires converge at a point, the sum of the currents flowing toward the point will be just equal to the sum of the currents flowing away from the point; or, in other words, the currents must balance.

KISH. The name "kish" is sometimes given in metallurgy to the carbon or graphite which appears on the surface of the iron in a blast furnace during the process of tapping. It is also used to designate the carbon which segregates in the form of plates in cast iron during the solidification.

KNIFE-EDGE BEARINGS. So-called "knife-edge" bearings are used on weighing and testing machines. When the knife-edge bearing as well as the seat are made of the proper material, the knife-edge will sustain loads up to 10,000 pounds per inch of length; but ordinarily about 5000 pounds is the usual limit of pressure. The knife-edge, as well as the seat bearing upon it, should be made from tool steel having a carbon content of from 0.9 to 1 per cent. The seats, after having been hardened, are drawn to a light straw color. The knife-edge is drawn to a slightly darker color. The knife-edge should be properly supported underneath its whole length in order to prevent deflection. The angle of the knife-edge should be 90 degrees for heavy loads. It should have a very slight flat at the extreme point, so small, however, that it is barely visible, because a pronounced flat or radius at the edge decreases the accuracy of the device. This flat may be obtained by rubbing with an oilstone. The seat against which the knife-edge bears, if made of an angular form, should be provided with a small round at the vertex of the angle.

KNIFE FILE. Files of this class derive their name from the fact that they resemble somewhat the blade of a knife. The section is tapering toward one edge and in a lengthwise direction toward the point. The teeth are double-cut, mostly bastard; this type is used quite generally for many purposes to which the knife shape is adapted.

KNUCKLE-JOINT EMBOSSING PRESS. Knuckle-joint power presses are used extensively for embossing coins, medallions, and other intricate

forms, as well as for lettering or embossing that requires a large amount of pressure for a comparatively short time. Because of their use for this class of work these presses are often termed "coining" presses. In the knuckle-joint embossing press, the slide is operated by two knuckle arms, the upper end of the top arm being attached to a bearing held stationary in a vertical plane by the frame. The knuckle arms are actuated by a crankshaft at the rear of the press, which is connected by a link to the joining ends of the knuckle arms. By this arrangement the arms are moved in and out relative to the frame as the crankshaft revolves. When the arms are straightened, the slide is forced down with a constantly increasing pressure on the work until the end of the stroke is reached. The increasing pressure is due to the fact that as the knuckle arms are straightened, the vertical movement of the slide is small, compared with the horizontal movement of the knuckle. It is this slow increasing pressure that distinguishes the knuckle-joint press from other types. Such a pressure enables the metal to flow under the force of the punch, and fine intricate embossing is possible.

KNURLING. The forming of a series of fine ridges upon the periphery of a circular part, such as a screw-head, handle, or knob, is known as *knurling* or *nurling*. The purpose of this checked or milled surface is usually to increase the grip of the hand and thus facilitate rotating the knurled part, although knurling is also done in many cases merely to produce an ornamental effect. The handles of gages and other tools are often knurled, and the round thumb-screws used on instruments, etc., usually have knurled edges. A knurling tool has a hardened disk or a set of disks mounted in a holder; when knurling, one or two of these disks (the number depending upon the type of knurling tool used) are pressed against the unhardened work, and rotate with it, thus reproducing upon the work the knurling which has been formed upon the periphery of the knurl itself. A common type of knurling tool is equipped with two knurls having teeth or ridges which incline to the right on one knurl and to the left on the opposite knurl. When these two knurls are pressed against the work as the latter revolves, one knurl forms a series of left-hand ridges and the other knurl right-hand ridges, which cross and form a diamond-shaped knurling. Knurling is done in the lathe either by a hand-controlled tool or by a tool which is held in the toolpost the same as for turning. The former method is known as *hand* knurling, and the latter, as *machine* knurling.

KO. This is a Chinese capacity measure, legalized in 1908, equal to 0.1035 liter, or 0.1094 quart.

KRUPP PROCESS. The Krupp armor plate process, consists essentially of repeated heating and cooling of the steel. After being cast, the ingot

is first heated to a uniform temperature, it is placed in a hydraulic forging press, then again heated and passed through the rolls, and then allowed to cool. After a preliminary heat-treatment, it is surfaced and cut; its surface is freed of scale, and then planed. After planing, the plate is put in the cementation furnace, in which it is gradually brought to the desired temperature and where it remains for weeks, and is then slowly cooled. When withdrawn from the furnace, the plate is again heated; it is then toughened by plunging into oil. When cooled, it is again heated, but to a lower temperature, and quenched in water. It is once more heated and placed in a press and bent to the desired shape. The plate is then annealed and allowed to cool, after which the final machining, drilling, and cutting operations are performed. It is then given its final heat-treatment. This consists in heating the face to a much higher temperature than the back. Both sides are then simultaneously douched with water, under pressure, which gives the face a glass-hard surface, but leaves the back in a very tough condition.

KWAN. Kwan is the Japanese unit of weight, equal to 3.75 kilograms or 8.2673 pounds avoirdupois. One kwan is divided into 1000 mommes.

KYANIZING. Kyanizing is a treatment applied to wood to render it proof against decay, by saturating it with a solution of corrosive sublimate (mercuric chloride, $HgCl_2$). The saturating is done either in open tanks or under pressure in closed tanks. Wood which is kyanized is used to a great extent by textile plants in structures that are subjected to acid fumes and conditions that produce rapid decay. In cases where the commercially treated wood cannot be obtained, the kyanizing has been satisfactorily accomplished in open wood tanks by using a solution composed of twelve gallons of wood or denatured alcohol and one gallon of corrosive sublimate (50 per cent solution). With this solution it is necessary for the wood to soak only about two minutes; but if it can be allowed to soak for half a day, the amount of alcohol used may be reduced to three gallons, and if the wood can be allowed to soak one week, no alcohol will be required at all.

LACQUER. Lacquer is the general name used for colored and frequently opaque varnishes used for applying a protective finish to metallic objects. Lacquer is applied to polished metal surfaces, such as brass, pewter, and tin, in order to give them a golden, bronze-like, or other lustrous surface. The main constituents of lacquer are shellac and alcohol, to which are added a number of other substances to give the required tint.

LAG SCREW. A large form of wood-screw having a square head (instead of the slotted form) so that it can be turned with a wrench. (See Wood-screws.)

LAMÉ'S FORMULA. Lamé's formula is the generally accepted formula for calculating the strength of cylinders subjected to high internal pressure. By means of this formula, the thickness of the metal of the cylinder can be determined when the inside radius, the maximum allowable fiber stress per square inch, and the pressure within the cylinder in pounds per square inch, are known. It is one of the more important engineering formulas, and will be found in engineering handbooks.

LAMP BASE AND SOCKET SHELL THREADS. The "American Standard" threads for lamp base and socket shells are recommended by the American Society of Mechanical Engineers and by most of the large manufacturers of products requiring rolled threads on sheet metal shells or parts, such as lamp bases, fuse plugs, attachment plugs, etc. There are four sizes, designated as the "miniature size," the "candelabra size," the "medium size" and the "mogul size." For table of dimensions see Machinery's Handbook.

LAMPBLACK. Lampblack is made by burning oils and is a very pure form of carbon. It has a specific gravity of 1.82, grinds in 75 per cent of oil, and has unusual tinting power, and is, therefore, used in large quantities for this purpose. Other characteristics are its great stability, its very slow rate of drying, and a preserving action on the oil with which it is combined. It resembles graphite in its property as a conductor of electricity.

LANCASHIRE PROCESS. The Lancashire process for producing wrought iron consists in melting pig iron between two layers of charcoal, the molten metal collecting in a pasty mass at the bottom of the furnace. In dropping to the bottom of the furnace, the molten iron passes through an air blast and is decarburized. The molten mass is permitted to remain at the bottom of the furnace for from 20 to 25 minutes, after which it is mixed with slag, remelted, and, while in a pasty state, formed into balls, removed from the furnace, and hammered or rolled. The process is used principally in Sweden, but also to some extent in the United States. It resembles the so-called "Walloon" process.

LAND. The term " land " as applied to metal-cutting tools such as taps, reamers, milling cutters, etc., refers to the top surface of a tooth. In the case of a tap, the land is the surface between two flutes, the land width being measured along the outer circumference from the front face of the tooth to the heel. The land of a reamer or milling cutter tooth is the top or clearance surface back of the cutting edge, but does not include the steeper slope at the rear which forms the back of the tooth and part of the flute or chip clearance space.

" LANDS " OF GEARING. The *bottom land* is the surface of the gear body between adjacent teeth. The *top land* is the surface of the tooth which is farthest from its supporting body.

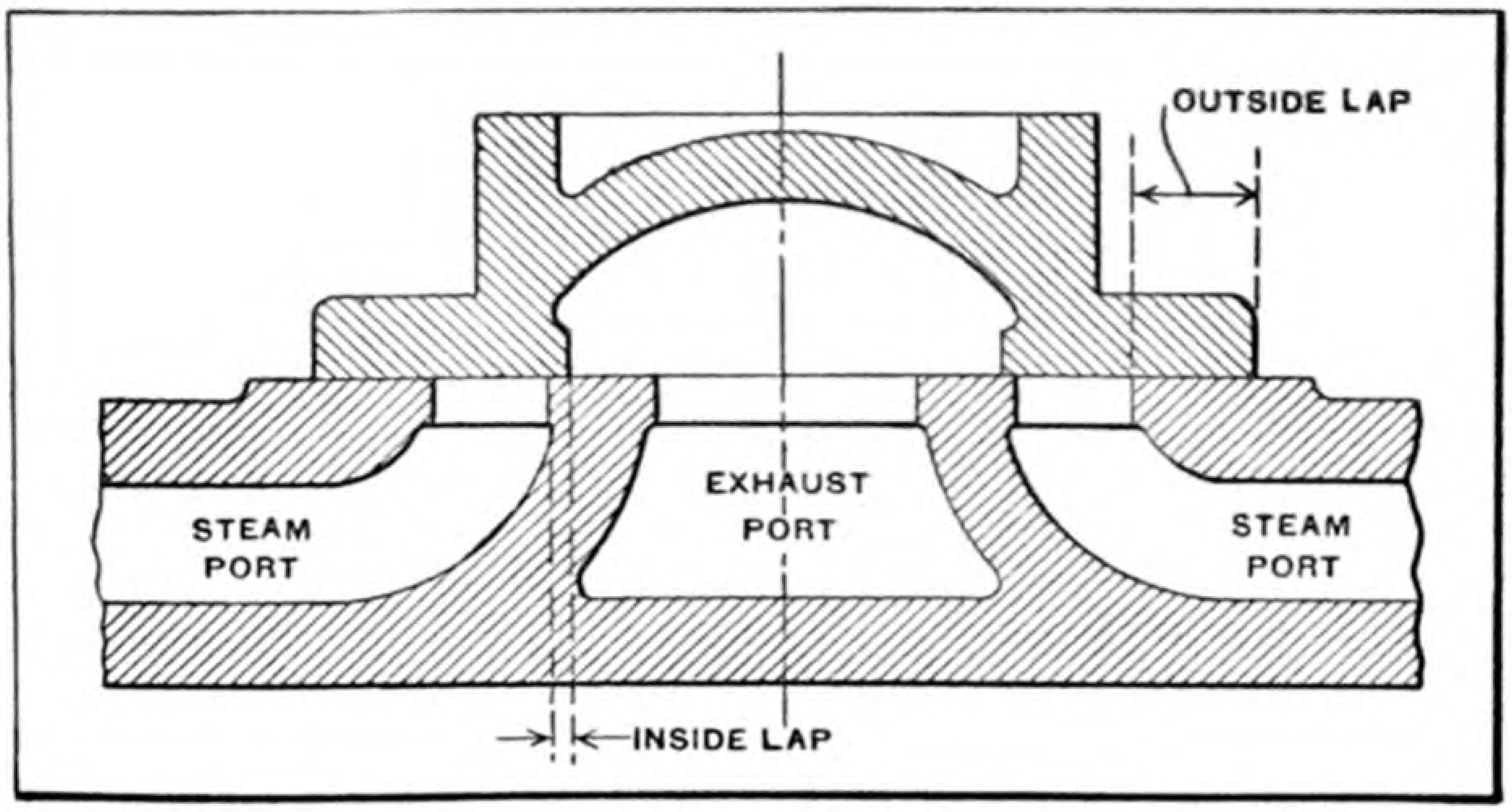
LANG'S LAY ROPE. In the regular type of wire rope, the wires of the strands are twisted in one direction and the strands themselves are laid into the rope in the other direction. In the Lang's lay rope, both the wires in the strands and the strands in the rope are twisted in the same direction. Such a rope is more easily untwisted than one made in the ordinary or " regular-lay " manner, and it is more difficult to tuck the strands securely in a splice, but the Lang's lay rope is, nevertheless, used to some extent, because it resists external wear and grip action much better than the regular-lay rope. This type of rope, however, should not be used unless assurance has been given by the rope manufacturers that it is adapted for the service for which it is intended. No universal rule can be given regarding its application, but its use is limited as compared with the regular-lay rope.

LANTERN PINIONS. Lantern pinions are formed of two disks between which are " rounds " of steel wire or rod to serve as teeth or " leaves." This type of pinion has been used extensively in clock mechanisms, and formerly was employed in connection with primitive millwright work. Lantern pinions are not adapted to driving, and in clock mechanisms they are the driven members. An accumulation of dirt that would stop the action of an ordinary cut pinion is simply pushed through between the rounds of a lantern pinion, which, therefore, continues to function. This is an important advantage of this type of pinion as applied particularly to low-priced clocks which frequently operate under unfavorable conditions.

LAP, DIAMOND. See Diamond Lap.

LAP OF SLIDE VALVE. The *outside lap* of a slide valve is the amount that the valve overlaps the outer edge of the steam port when the valve is in the central position over the ports. (See illustration.) If a valve did not have outside lap, steam would be admitted for the full length of the piston stroke; hence, the point of cut-off in the case of a single slide valve depends upon the amount of outside lap, the greater the lap, the

earlier the cut-off, and the greater the expansion of the steam. The *inside lap* is the amount that the valve overlaps the inner edge of the steam port when in mid-position. Increasing the inside lap increases compression and delays the point at which the steam is released from the cylinder, whereas diminishing the inside lap decreases compression and hastens the point of release.



Slide Valve in Central Position over Steam and Exhaust Ports

LAPPING. Lapping is a refined abrading process generally employed for correcting errors in hardened steel parts and securing a smooth surface, or for reducing the size a very small amount. The lap is made of some soft metal, such as cast iron or brass, and it is " charged " with an abrasive which is imbedded into its surface. The grade or coarseness of the abrasive depends upon the finish required and the amount that must be removed by lapping. The form of the lap naturally depends upon the shape, size, and location of the surfaces upon which it is used.

LAPPING MACHINES. There are several types of lapping machines. One special design used for lapping precision gage blocks has two flat laps of circular form. The lower lap is attached to the base of the machine, and the upper lap is secured to an arm by a connection which permits the lap to move freely in any direction but not to revolve. This arm is pivoted at one end so that the upper lap can be swung to one side to expose the lower lap and the work. When a machine is in use, one lap is above the other, and the gage blocks are between them, so that both the upper and lower surfaces of the blocks are lapped simultaneously. When the blocks are to be removed or inserted in the machine, the upper lap is swung out of the way. Between these two cast-iron laps, there is a steel plate or " spider " which contains holes into which the blocks to be lapped are inserted. The upper and lower laps remain stationary, while the spider

receives a planetary motion which brings each block into contact with the entire surface of each lap.

Lapping Machine for Piston-pins. — A machine, designed for lapping automobile piston-pins or parts of similar shape, is equipped with two lapping wheels between which there is a spider for holding a number of pins in position. In operation, the upper lap is lowered on the pins, and the variation in the lapping wheel speeds causes the pins to rotate and creep slowly in a circular path. There are, in fact, three movements of the pins which insure accurate results.

Lapping Piston-rings. — A lapping machine designed for piston-rings has two cast-iron laps which remain stationary, while a number of rings supported by a work-carrier are given a series of short circular movements combined with a slow rotary motion. The production of precision gage-blocks by mechanical lapping demonstrated the possibilities in this direction.

Lapping Crankshaft Bearings. — A machine for polishing automobile crankshaft bearings is known as a lapping machine, although it employs felt polishing wheels which are charged with a fine abrasive. These wheels are of a width to suit the bearings and they rotate at 1500 revolutions per minute while the crankshaft revolves at a much lower speed

LAPPING MACHINE, UNIVERSAL. This machine has been designed for tool room work such as gage blocks, plug gauges and similar precision work. It can be adapted for lapping angular work such as thread cutting tools, form tools and similar pieces where angles and faces need to be accurate, flat, and highly finished. Both cylindrical and flat work can be finished by using suitable workholders.

LARD OIL COMPOUNDS. Lard oil compounds for use as cutting lubricants, should be stable blends of lard oil with other oils which will give to the compound the properties undiluted lard oil lacks. The diluent must be a liquid (rather, an oil) which can be added to the lard oil in any proportion that experience shows to be the most effective for the particular work the compound is to perform.

The source of such diluents is the petroleums, the mineral oil distillates of which can be obtained in numerous varieties. The proportions of mineral and lard oils vary, of course, as does also the viscosity of the mineral oil constituent, depending upon the nature and the severity of the work to be done. The mineral oil may be one of the pale amber mineral oils of medium viscosity, as used in the lard oil compounds suitable for high-speed operations, where a constant and abundant stream of cutting oil is required, or it may be a heavy-bodied viscous oil which is compounded with the lard oil for use in heavy, coarse work.

Classification of lard oil compounds has been carried out by certain

leading producers of cutting lubricants. For instance, there are lard oil compounds designated by number, the number indicating the percentage of lard oil contained in the compound. With such an index as a guide, and the nature of the work to be performed known, a lard oil compound may be selected for any particular operation, embodying the qualities that experience has shown to be required.

LATENT HEAT. Latent heat is the heat which disappears when a solid is changed to a liquid, or a liquid to a gas, the former being called the *latent heat of fusion*, and the latter, the *latent heat of evaporation*. The heat which disappears in this manner is converted into mechanical work, and is used in tearing apart the molecules, and, hence, produces no change in the temperature of the substance. When the gas changes back to a liquid, or the liquid to a solid, the latent heat is again given out. The action described may be illustrated by the melting of ice into water, and the evaporation of the water into steam. When heat is applied to a piece of ice in an open vessel, it gradually melts, but the temperature of the water remains at 32 degrees until all of the ice has been melted, the heat having been used in the process of changing the ice into water. If heat is still applied, the temperature of the water will rise until it reaches 212 degrees F., at which point evaporation takes place, and although heat is constantly applied, the temperature of the water remains constant until it is all evaporated into steam. If the steam were collected and condensed, and the water cooled to 32 degrees F. and frozen, all of the heat which had been supplied would again be given out. Latent heat plays an important part in the operation of a boiler and the generation of steam. When it is said that the latent heat of evaporation of water is 966.6, this means that it takes 966.6 heat units to evaporate one pound of water after it has been raised to the boiling point, 212 degrees F

LATHE CLASSIFICATION. As lathes in general are used for a great variety of operations, naturally there are many different designs and sizes. The various types are usually classified, either with respect to some characteristic constructional feature, or with reference to the general class of work for which the lathe was designed. The most common type of lathe is usually known by manufacturers as an *engine lathe*. The term " engine," as used in this connection, simply means a machine, and it serves to designate that particular class of lathe which is hand manipulated and used by machinists for general work. In ordinary shop usage, the word " lathe " is commonly used to indicate a lathe of this class. Lathes having gears which are changed for cutting threads of different pitch are sometimes known as *plain* or *standard* engine lathes, whereas those having a gear-box by means of which the necessary gear combinations may be obtained by

simply shifting one or two levers are usually known as the "quick change-gear" type. The *tool-room* or *toolmakers' lathe* is classified according to the general class of work for which the lathe is designed. It is similar in appearance to an ordinary engine lathe, but has extra attachments and is generally considered a very accurate machine.

Other types of lathes which have some distinguishing characteristic are: The *turret lathe*, which is so named because tools for performing successive operations are held in a revolvable turret; the *bench lathe*, which is so small that it is mounted on a bench, and intended for delicate work usually requiring considerable accuracy; the *precision lathe*, which is usually a bench type that is capable of very accurate work and is more expensive than an ordinary bench lathe; the *gap lathe*, which has a gap formed in the bed in front of the faceplate in order to increase the "swing" or maximum diameter that may be revolved; the *extension gap lathe*, which has a double form of bed, the upper section of which may be extended in order to form a gap for increasing the swing, and also the distance between the centers; the *crankshaft lathe*, which is especially arranged for turning crankshafts; the *wheel lathe*, which is a large design intended especially for turning locomotive driving wheels; the *axle lathe*, which is a powerful design for turning car axles; the *foot-power lathe*, which is driven by a foot-treadle and is intended for small work; the *speed lathe*, which is without back-gears and is used for rotating parts rapidly for polishing, hand turning, or filing; the *chucking lathe*, which is especially adapted for parts that must be held in a chuck while being operated upon; and the *automatic lathe*, which is designed for the duplicate production. See Automatic Lathe; Bench Lathe; Blanchard Lathe; Burnishing Lathe; Capstan Lathe; Facing Lathe; Turret Lathes.

LATHE DEVELOPMENT. An early treatise by Moxon, published in 1680, in England, shows that at that time the lathe had developed to a point where it was possible to turn out high-class ornamental woodwork, including oval shapes, but anything more than this was beyond its capacity until the slide-rest was invented. (See Slide-rest Development.) About 1800, Maudslay provided his lathe, having a slide-rest, with lead-screw and change-gears, and from then onward the development of the modern machine tool has been continuous and rapid. This combination is distinctly Maudslay's, and deserves to be classed as one of the greatest inventions of history. In the South Kensington Museum (London) are three lathes which show how rapidly the idea developed. The first is an old wooden pole lathe, with two dead centers set in wooden blocks. A string or strap went from a foot-treadle below, around the piece to be turned, and up to a wooden spring-pole attached to the ceiling. By working the

treadle, the piece was rotated alternately backwards and forwards, the cut being made with a hand tool during the forward movement. This lathe fairly represents the state of the art in 1800. The second is one of Maudslay's first screw-cutting lathes. It has two triangular bars for a bed, cast-iron head- and tail-stocks, and a lower spindle in the headstock between the bars connected to the live spindle by a single pair of gears. This lower spindle carried on the end toward the slide-rest a forked clutch into which was fitted a lead-screw of the desired pitch, which controlled the longitudinal movement of the tool. When a screw of another pitch was desired, the lead-screw was changed for one of the required pitch. This machine was built about 1797. The third machine was built in 1800. It has a well-designed cast-iron bed, a single lead-screw with 30 threads to the inch, change-gears, and a strong, well-built carriage with a back-rest to prevent the springing of the work. There are 28 change-gears with teeth varying in number from 15 to 50. With the machine are sample screws, about 2 feet long, which were cut on it, with threads varying from 16 to 100 threads per inch. Shortly before his death in 1831, Maudslay built a lathe having a faceplate 9 feet in diameter, capable of turning flywheels 20 feet in diameter and boring steam cylinders up to 10 feet in diameter.

LATHE SIZE. The size of an engine lathe, according to the practice followed in the United States, is based upon the "swing" or the maximum diameter that can be rotated over the ways or shears of the bed. The nominal sizes listed by lathe manufacturers, however, ordinarily do not represent the maximum swing, but a diameter which is somewhat less. For instance, a lathe which is listed as a 24-inch size may actually swing $24\frac{1}{2}$ or 25 inches. The variations between the nominal and actual sizes range from about $\frac{1}{2}$ to $\frac{3}{4}$ inch up to $1\frac{1}{2}$, or even 2 inches. According to the English practice, the size of a lathe is defined by the height of the centers above the top of the bed.

LATHE TOOLS, RIGHT- AND LEFT-HAND. The tools used on lathes may be either right-hand or left-hand, depending upon the location of the cutting end. According to common usage, lathe tools are classed as "right-hand" when the tool is adapted for cutting from right to left, the cutting edge being on the left-hand side as the tool is seen from above. Thus, a right-hand side tool, for example, is adapted for facing the right-hand side of a collar or the right-hand end of a shaft, and vice versa for left-hand side tools. The "hand" of a lathe tool, therefore, seems to be related to the location of the surfaces the tool is adapted for cutting, rather than to the position of the cutting edge, since a right-hand tool has its edge on the left-hand side, as seen from the top, and the reverse is true for a left-hand side tool. See also Planer Tools, Right- and Left-hand.

LATIMER-CLARK CELL. This is a primary cell or battery having a zinc anode, a mercury cathode, a zinc sulphate electrolyte, and a paste of mercurous sulphate and zinc sulphate for a depolarizer. This is a so-called "standard cell" producing 1.43 volts at 15 degrees C.

LATTEN ALLOY. Latten is an alloy of copper and zinc, and belongs, therefore, to the class of alloys generally known as brasses. Latten is made in thin sheets and used especially for monumental brasses and figures. It is made in three commercial forms; black latten, which is rolled but unpolished; shaven latten, which is unpolished, but of extreme thinness; and rolled latten, which may be similar to either black or shaven latten in thickness, but which has both sides polished.

LAVITE. "Lavite" is a trade name for certain salt baths used in heat-treating steel. These salt-bath heating mediums may be used for a wide range of temperatures, varying from 500 degrees F. for tempering up to 2300 degrees F. for heating high-speed steel for hardening. A Lavite bath transmits heat to steel in a manner quite different from a lead bath or an oven furnace. When the steel is introduced into a bath of carbon steel Lavite, which has a melting point of 1300 degrees F., the Lavite freezes around the steel, and forms an insulating jacket which prevents too rapid transfer of heat in the initial stages of the heating period. This jacket is also slow in melting, and the composition of "Lavite" is such that the melting of the jacket proceeds at a rate that permits of a uniform transmission of heat to the metal. The high specific heat of "Lavite" and its high heat of fusion account for the slow rate at which the insulating jacket melts. When the temperature of the steel has reached 1300 degrees F., the jacket has entirely disappeared, and at this point also, there is a favorable condition for heat transfer, because the temperature difference between the steel and the bath is comparatively small. Beyond 1300 degrees F., the full heating effect of the bath is obtained, and this effect is enhanced by the low viscosity of the salt bath, which permits free circulation of the heated salt around the steel.

With lead, no insulating jacket — or at best a very thin jacket — is formed.

LAW CELL. This is a primary cell or battery in which the anode is made from zinc, the cathode from carbon, and the electrolyte is a solution of ammonium chloride (NH_4Cl). The cell produces from 1.3 to 4 volts and is used for open-circuit work. No depolarizer is employed.

LAW OF CHARLES. See Charles' Law.

LAW OF CONSERVATION OF MASS. This is a chemical law, applying to all chemical reactions, which states that whenever a change in the

composition of substances takes place, the amount of matter after the change is the same as before the change.

LAW OF MULTIPLE PROPORTION. Same as Dalton's law.

LAW OF SINES AND COSINES. In a triangle, any side is to any other side as the sine of the angle opposite the first side is to the sine of the angle opposite the other side; or, if a and b be the sides, and A and B the angles opposite them:

$$\frac{a}{b} = \frac{\sin A}{\sin B}.$$

In a triangle, the square of any side is equal to the sum of the squares of the other two sides minus twice their product times the cosine of the included angle; or if a, b, and c be the sides and the angle opposite side a be denoted A, then:

$$a^2 = b^2 + c^2 - 2\,bc \cos A$$

and

$$a = \sqrt{b^2 + c^2 - 2\,bc \cos A}.$$

These two laws, together with the proposition that the sum of the three angles equals 180 degrees, are the basis of all formulas relating to the solution of triangles.

LAYING-OUT PLATE. Surface plates are sometimes formed of large castings which are mounted on a special bed. Large plates of this kind are commonly used to provide a flat surface for laying out machine parts rather than for testing the accuracy of flat surfaces and they are commonly known as laying-out plates.

LAY OF WIRE ROPE. The lay of wire rope is the distance parallel to the axis of the rope in which a strand makes one complete turn about the axis of the rope. The lay of the strand, similarly, is the distance in which a wire makes one complete turn about the axis of the strand. According to U. S. Government specifications, wire rope shall be regular lay; that is, the strands shall form a helix about the axis of the rope similar to the threads of a right-hand screw and the wires form a left-hand helix about the axis of the strand. The lay of the wires in the strand should make them approximately parallel to the axis of the rope where they would come into contact with a cylindrical surface which inclosed the rope. Seizing strand shall be standard lay; that is, the wires shall form a helix about the axis of the strand similar to the threads of a left-hand screw. The lay of wire rope shall be obtained by measuring, parallel to the axis of the rope, the distance in which a strand makes five or more complete turns around the rope. This distance divided by the number of turns is the lay of the rope. When

measuring the lay, there shall be no axial load on the rope, and the measured distance shall not be within 10 feet of the end of the rope.

LAY-OUT LINES, COATINGS. See Coatings for Laying-out Lines.

LEAD AND ITS PROPERTIES. Lead rarely occurs free in nature, and then only in minute quantities, but it is found abundantly in combination with other elements. Its strength in both compression and tension is very small, so that it cannot be drawn into fine wire, although it can be rolled into very thin sheets. The most important lead mines are in Nevada and Colorado, and in England, Wales, Germany, Spain, Mexico, and Brazil. As lead unites readily with almost all other metals, it is used in many alloys for bearing metals, electrotype metal, type metal, "white metal," etc. Alloys composed of lead, bismuth, and tin are noted for their low melting points. The chief uses for lead, except in alloys, are for service pipes in water piping, as a base for a number of paints, and for shot and bullets. Lead is easily dissolved in nitric acid; it is dissolved in acetic acid only when in contact with air; and is scarcely affected by sulphuric acid lower than 66 degrees Baumé. Hydrochloric acid attacks it very slowly, because of the layer of insoluble chloride formed. The chemical symbol of lead is Pb; atomic weight, 207.1; melting point, 327 degrees C. (621 degrees F.); linear expansion per unit of length, per degree F., 0.0000157; specific heat, 0.031; and conductivity for both heat and electricity (silver = 100), 8.5. The ultimate tensile strength of cast lead is about 2000 pounds per square inch; and the ultimate tensile strength of lead pipe, about 2200 pounds per square inch. The specific gravity of lead varies from 11.35 to 11.37, and, hence, its weight per cubic inch equals 0.41 pound. It vaporizes at a bright-red heat and burns at from 1480 to 1540 degrees C. (about from 2700 to 2800 degrees F.).

Lead in Bearings. — Lead flows more easily under pressure than any of the common metals, and it has great anti-frictional properties. A number of metals exceed lead in this property, but their cost or some other factor render them unavailable. As the amount of lead that is used in a given bearing is increased, the lower the frictional resistance; the bearing also becomes softer and less expensive. Lead, however, is too soft to be used alone, as it cannot be retained in the recesses of the bearing even when used simply as a liner and run into a shell of brass, bronze, gun-metal, or some other alloy. Hence various other metals are alloyed with it, such as tin, antimony, copper, zinc, iron, and a number of non-metallic compounds, such as sodium, phosphorus, and carbon. If antimony is added to lead, the hardness and brittleness is increased and if tin is added as well, it makes a tougher alloy than lead or antimony alone. Nearly all of the various babbitt metals are alloys of lead, tin, and antimony in various

proportions, with or without other ingredients. In such babbitts, the wear increases with the amount of antimony and the price with the amount of tin. The higher antimony babbitts are used in heavy machinery, as they are harder, while those low in antimony are used in high-speed machinery.

LEAD BATHS. The lead bath is extensively used in connection with the heat-treatment of steel, but is not adapted to the high temperatures required for hardening high-speed steel, as it begins to vaporize at about 1190 degrees F., and, if heated much above that point, rapidly volatilizes and gives off poisonous vapors. Lead furnaces should be equipped with hoods to carry away the fumes. Lead baths are especially adapted for heating small pieces that must be hardened in quantities. Gas is a satisfactory fuel for heating the crucible. It is important to use pure lead that is free from sulphur. Melting pots for molten lead baths, etc., should preferably be made from seamless drawn steel rather than from cast iron. Cast-steel melting pots, if properly made, are as durable as those made of seamless drawn steel.

LEAD BURNING. Lead burning may be defined as a form of autogenous welding, by means of which the parts to be united are joined by melting metal between them. This molten metal is obtained by heating the end of a strip of lead of the same composition as that of the lead plates to be united The addition of metal at the joint is not actually necessary, but it serves to replace the material that is usually cut away before welding. The term " lead burning " is really a misnomer, because the lead is not burned so long as the welder does the work properly. The operation is essentially one of welding the lead with heat furnished by the combustion of hydrogen, and the technique of the operation is almost exactly the same as that of ordinary oxy-acetylene welding. Lead burning may be effectively performed with an oxy-acetylene welding torch, but great care must be taken, because the temperature of the oxy-acetylene flame is really too high for working on lead.

LEADED BRONZE. This is an alloy containing 80 per cent of copper, 10 per cent of tin, and 10 per cent of lead, which melts at 945 degrees C. (1735 degrees F.).

LEADED GUN-METAL. This is an alloy containing about 85 per cent of copper, 2 per cent of zinc, 10 per cent of tin, and 3 per cent of lead, melting at a temperature of 980 degrees C. (1795 degrees F.).

LEAD FOIL. See Tin Foil and Lead Foil.

LEAD JOINT. This is a term generally used to signify the connection between pipes which is made by pouring molten lead into the annular space

between a bell and spigot, and then making the lead tight by calking. The term is rarely used to mean the joint made by pressing the lead between adjacent pieces, as when a lead gasket is used between flanges.

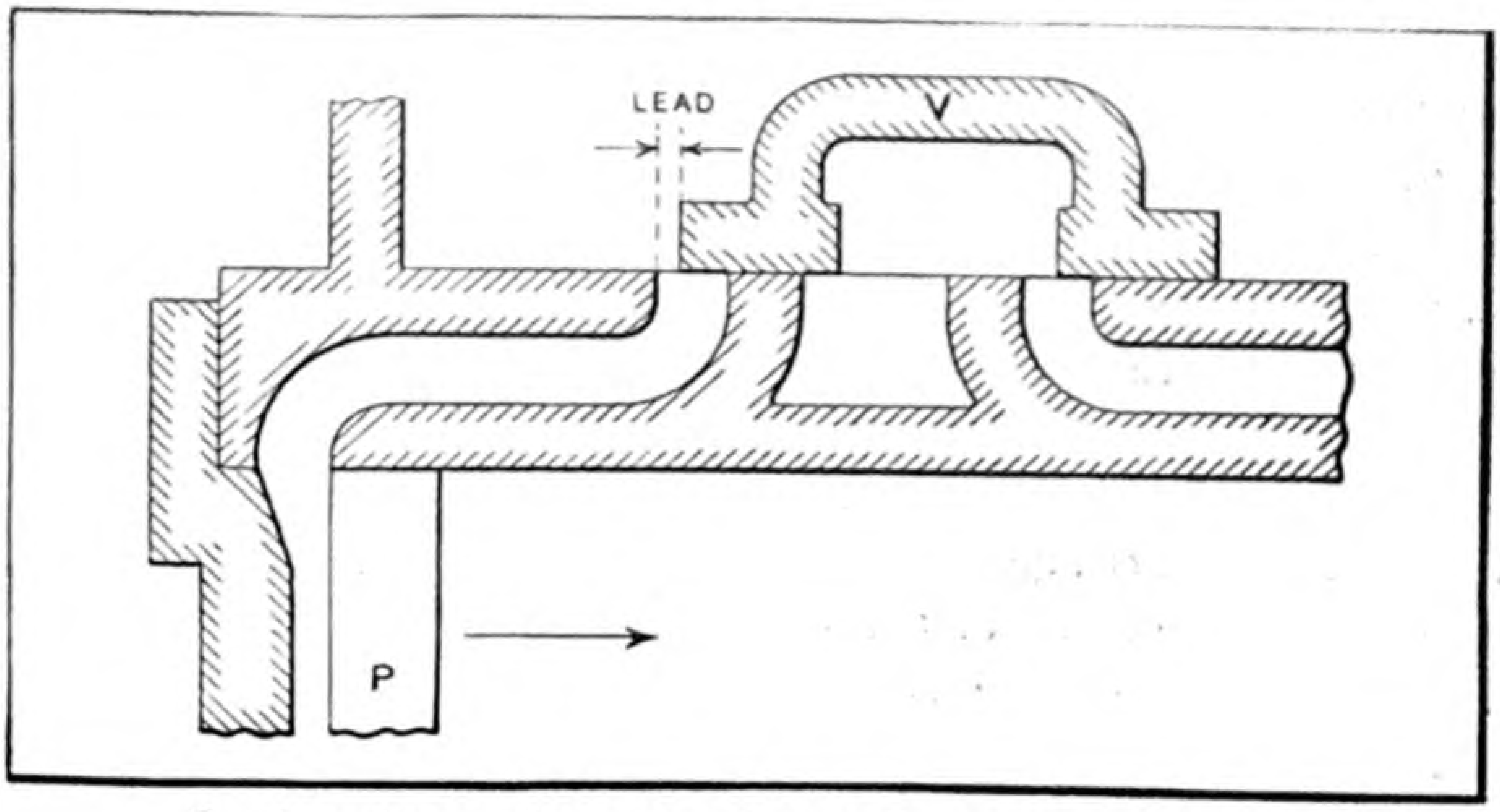
LEAD MONOXIDE. See Litharge.

LEAD OF MILLING MACHINE. The lead of a helix (or "spiral" as it is commonly called) that would be generated in a milling machine during one revolution of the dividing-head, when the dividing-head is connected to the table feed-screw by gearing giving a speed ratio of 1 to 1, is known as the *lead of the machine*. Suppose the table feed-screw has 4 threads per inch, that 40 turns of the indexing crank or worm-shaft are required for one revolution of the dividing-head spindle, and that the worm-shaft and feed-screw are connected by gearing which causes them to rotate at the same speed; then, 40 turns of the feed-screw will be required for one complete revolution of the dividing-head spindle, and, as the feed-screw has 4 threads per inch, the total lengthwise movement of the table for one revolution of the dividing-head spindle will equal $40 \div 4 = 10$ inches; therefore, the lead of the spiral generated during one revolution of the dividing-head spindle will equal 10 inches, which is the lead of this particular milling machine.

LEAD OF SCREW THREADS. The lead of a screw thread is the distance the screw will travel forward in the nut if revolved one complete revolution. The lead of a screw thread should be distinguished from the *pitch* of the thread, which is the distance from center to center of two adjacent threads. In a single-threaded screw, the pitch and the lead are equal. If the screw is provided with a double thread, then the lead equals two times the pitch. In a triple thread, the lead equals three times the pitch. In designating a single-threaded screw thread, it is sufficient to give either the pitch or lead of the thread, but, in designating multiple-threaded screws, it is advisable to give both the lead and the pitch in order to fully describe the thread. For example, a screw may be described as having "double thread, $\frac{1}{2}$-inch lead, $\frac{1}{4}$-inch pitch." When so described, misunderstanding as to the meaning of lead and pitch is impossible, and mistakes in the shop are avoided.

LEAD OF SLIDE-VALVE. The lead of a slide-valve is the amount of port opening when the piston is at the end of its stroke and the engine is on the dead center. This is the condition in the illustration, for the piston *P* is ready to start on its forward stroke, as indicated by the arrow. With the piston in this position the valve has already opened a distance equal to the lead, and the steam has had an opportunity to enter and fill the clearance space before the beginning of the stroke, thus giving the piston

full steam pressure at this point. The lead ordinarily varies on engines of different size, from 0 to about $\frac{3}{16}$ inch, $\frac{1}{16}$ inch being a fair average for ordinary slide-valves. The amount of lead is sometimes determined by experiment after the engine is erected. When there is little or no lead, the tendency is for the piston to move under reduced pressure through part of its stroke, especially if the ports are small and the clearance space large. In some cases, however, a small amount of lead gives good results,



Lead or Steam Port Opening at Beginning of Stroke

especially when the compression is sufficient to produce a pressure at the beginning of the stroke nearly equal to the boiler pressure. Naturally a quick-acting valve requires less lead than one that opens more slowly.

LEAD PIPE. Lead pipe is used to a very large extent for water systems for domestic purposes. It has been used for this purpose for centuries with entire satisfaction. Lead pipe for water systems, made from pure lead, is considered harmless as regards its influence on health, but mixtures with other metals, such as zinc, antimony, or tin, are dangerous and objectionable. The ultimate tensile strength of lead may be assumed to vary from 1600 to 2400 pounds per square inch. It is difficult to give the strength of lead with any certainty, because lead produced in Missouri, for example, is very much harder and stronger than so-called "desilverized" lead, and pipe made from the harder lead will stand a greater pressure.

LEAD-PROOF. A term applied to a method of testing the impression in a drop-forging die. See Drop-forging Dies, Lead-proof.

LEAD-SCREW. The lead-screw of an engine lathe is used for feeding the carriage when cutting threads. The carriage is engaged with this screw by means of two half-nuts that are free to slide vertically and are closed around the screw by operating a lever. Any screw which performs

a similar function on other machine tools may properly be classed as a lead-screw.

LEAD-SCREW ERRORS. Errors in a lathe lead-screw may be compensated for by equipping the carriage with a special lead-screw nut, which may be turned slightly forward or backward when cutting a precision screw, in order to advance or retard the movement of the carriage and thus counteract the errors in the lead-screw of the lathe. The rotary movements of the nut are regulated according to the errors in the lead-screw, and may be controlled by a templet which causes a lever connecting with the nut to be raised or lowered as the carriage traverses along the bed. While this method of compensating for errors is simple in principle, it is not easily applied because of the difficulty of determining the location and magnitude of the local errors along the lead-screw, which should be cut as accurately as possible to begin with, if intended for a precision screw-cutting lathe. The general method of locating the errors is by comparing the movements of the carriage derived from complete turns of the lead-screw, with a very accurate scale of the kind found on some measuring machines. The templet for controlling the rotary movements of the lead-screw nut is then laid out according to the errors at different points along the lead-screw.

LEAD-SCREW STEEL. Lead-screw steel is a better grade than machine steel, and contains from 0.60 to 0.70 per cent carbon. Where machine parts are subjected to strain and shock such as shafts, studs, arbors, etc., which require a tough steel without hardening, lead-screw steel is commonly used.

Properties. — Weight, 0.283 pound per cubic inch; 485 pounds per cubic foot. Specific gravity, 7.75. Strength: tension, 90,000 pounds per square inch; shear, 60,000 pounds per square inch. Melting point, 2600 degrees F.

LEAD WOOL. Lead wool is made of lead which has been shredded to about the size of heavy thread. After being shredded, the lead fibers are either collected in bundles and twisted together somewhat, or they are supplied in continuous strands coiled on reels. Lead wool is used principally for calking pipes, the lead being forced into the joint cold against a backing of hemp or tarred yarn. It is considered a good substitute for molten lead in calking joints for gas mains. The use of lead wool decreases the cost as compared with the use of molten lead. Very uniform results are obtained by the use of lead wool, especially when calked with pneumatic hammers.

LEAF-SPRINGS. See under Springs.

LEATHER, ARTIFICIAL. There are various applications of artificial leather in machine construction, such as washers of one kind or another, machine clutches, and shields for covering handles of machine levers. Artificial leather can be punched out to the required shape just as easily as natural leather.

Artificial leather is made from waste materials, largely from boot and shoe factories, but if properly prepared, it is equal to the best hide leather in strength, and has the advantage of not heating up as readily. Artificial leather can be employed as an insulating material in electric machines, but here it is important that the material should be heavily rubberized. Rubberized artificial leather for the preparation of these insulators utilizes rubber waste as well as leather waste.

LEATHER, EFFECT OF HUMIDITY. The strength and elasticity of leather are greater in moist air than in dry, and for that reason it is important in making comparative tests of leather to be sure that they are made under the same humidity conditions. A given piece of leather tested in a dry atmosphere might appear to be weaker than a much poorer piece of leather tested in moist air. Experiments have shown that an increase of from 35 to 55 per cent in relative humidity increases the strength of leather 13 per cent and the stretch 16 per cent. When the humidity was raised from 35 to 75 per cent, the average increase in strength was 42 per cent and in stretch 53 per cent.

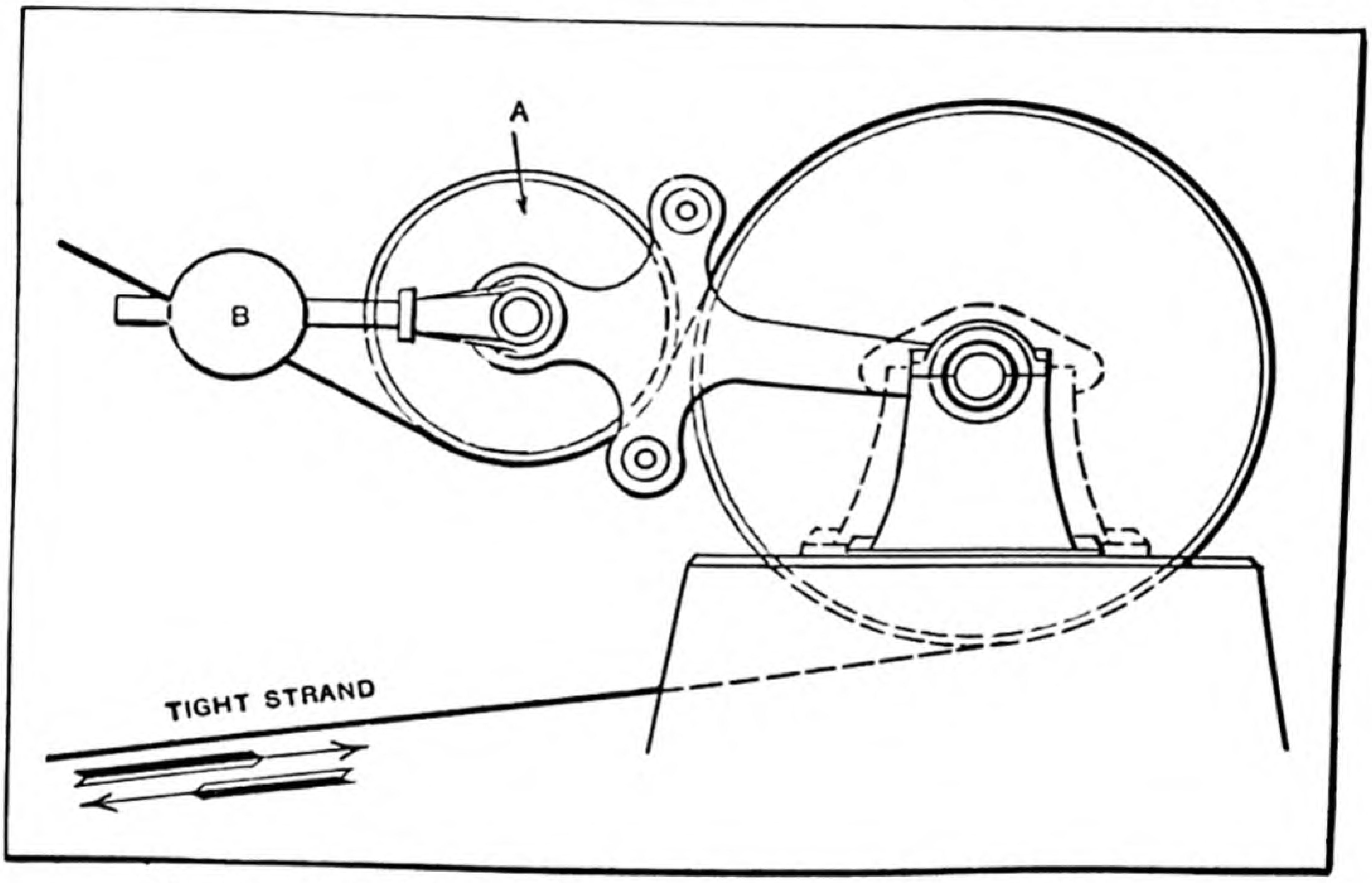
LECLANCHÉ CELL. This is a primary cell or battery having a zinc anode and a carbon cathode, with a solution of ammonium chloride (NH_4Cl) for the electrolyte, with a manganese dioxide depolarizer. The cell is used for open circuits, and gives a voltage of from 1.4 to 1.7 volts. The carbon cathode is placed in a porous cup which is filled with the manganese dioxide in the form of a coarse powder.

LEDRITE BRASS ROD. Ledrite brass rod is a free-cutting material which is especially adapted for high-speed machining operations in connection with screw machine practice. It has long been known that the addition of a small amount of lead imparts free-cutting qualities to brass, as indicated by the fact that the chips have a tendency to break up into short pieces and thus prevent fouling the tools. This free-cutting action depends upon the fact that the lead is distributed as fine globules throughout the mass of the metal. The more thoroughly the molten metal in the melting furnace is stirred, the more finely will the lead be divided and the more evenly will it be distributed through the metal; thus greater uniformity of cutting properties results. Ledrite brass rod is one of the products of the electric furnace.

LEGHORN CONVERTER. This converter is also known as Bisbee converter and trough converter. See Trough Converter.

LENGTH STANDARDS. See Standards of Length; also Light Wave as Length Standard

LENIX BELT DRIVE. The Lenix type of short-center belt drive is an arrangement whereby a resilient tension roller *A* (see diagram) pivoted either concentric or eccentric to the axis of the smaller pulley (driving or driven) swings around this pulley, thus increasing or decreasing the arc



Tension Roller or Idler for Short-center or Lenix Belt Drive

of contact, depending on the increasing or decreasing of the load, and thereby maintaining the same stress in the slack side, regardless of the elongation of the belt. The adjustable weight *B* provides means of varying the tension. This belt drive was invented about 1900 by a French engineer-officer named Leneveu, but the credit for developing the short-center belt drive in a scientific way, undoubtedly belongs to the Berlin-Anhaltische Maschinenbau A. G., in Dessau, Germany, through whose efforts the drive has become well known under the name of "Lenix."

LEVELING ROD. One of the instruments used in surveying is the leveling rod. It consists of a wooden rod, usually 6½ feet high, graduated to hundredths of a foot, and provided with a sliding target. The rod is made in two parts, so arranged that its length can be extended to 12 feet. The target is provided with a vernier for accurate work, reading to thousandths of a foot. In using, the rod is held in a vertical position with its

lower end resting upon the point, the elevation of which is desired, and the target moved up or down until its center coincides with the cross-wires of the telescope of the level. The reading of the elevation is made from the rod on a line corresponding with the center line of the target. There are several forms of rods in common use, some of which are read by the rodman, while others are read through the telescope of the level.

LEVELS. The accuracy of a spirit level depends entirely upon the curvature of the glass tube. This tube is ground on the inside to a barrel shape, except in cheap levels which simply have a glass tube bent to the approximate curve. The bent-tube type is not to be recommended except for work which does not require great accuracy. The tube is nearly filled with spirits of wine, ether, or some similar fluid, and is hermetically sealed at each end. The larger radius of curvature the glass has, the more sensitive will be the level. The air space in a ground glass is much longer than in a bent one, being ordinarily from one-fourth to one-third the length of the tube. Modern levels are graduated to tenths and twentieths of an inch, except when they are divided according to the metric system.

Level Glass Mounting. — The leveling glass or "bubble" of a level is generally fixed in a brass tube with plaster-of-paris. This method has been found to be satisfactory for all levels having an accuracy of about five seconds angular measurement to each one-tenth inch graduation. For finer levels, it is better to fix one end only with plaster-of-paris and the other with cork, because, if the glass is fixed rigidly at both ends with plaster-of-paris, there will be a strain on the level due to temperature changes, and, as the expansion of glass and brass is different, a slight inaccuracy is liable to result. It is also advisable to have an extra glass tube surrounding the leveling tube for very accurate levels, in order to provide insulation from the heat of the hand. A level of one minute angular measurement to one-tenth inch graduation is the most serviceable for general use. One having an accuracy of 30 seconds to one-tenth inch should be used on a floor free from vibration. Finer levels are used mostly on surveying and astronomical instruments.

LEVER. A lever is the simplest element of a machine and may be defined as a bar used to exert a pressure or sustain a weight at one point in its length, by the application of a force at a second, and turning at a third on a fixed point called a *fulcrum*. The rotating effect of a force about a fulcrum is termed the *moment of the force* and equals the product obtained by multiplying the force by the perpendicular distance to the fulcrum. If the force is measured in pounds and the distance in feet, the moment is measured in foot-pounds; if the force is measured in pounds and the distance in inches, the moment is measured in inch-pounds; if the force is

measured in tons and the distance in feet, the moment will be in foot-tons, etc. The most common unit for measuring moments, however, is in foot-pounds. The most important principle to be observed with regard to moments is that the distance from the fulcrum to the force, generally called the "lever arm," must be measured on a line at right angles to the direction of the force, as shown in Fig. 1.

The principle of moments is applied to a lever by the following rule: When two or more forces act upon a rigid body and tend to turn or rotate it about a fulcrum or axis, then, in order that equilibrium may exist, the sum of the moments of the forces which tend to turn the body in one direction must equal the sum of the moments of the forces which tend to turn

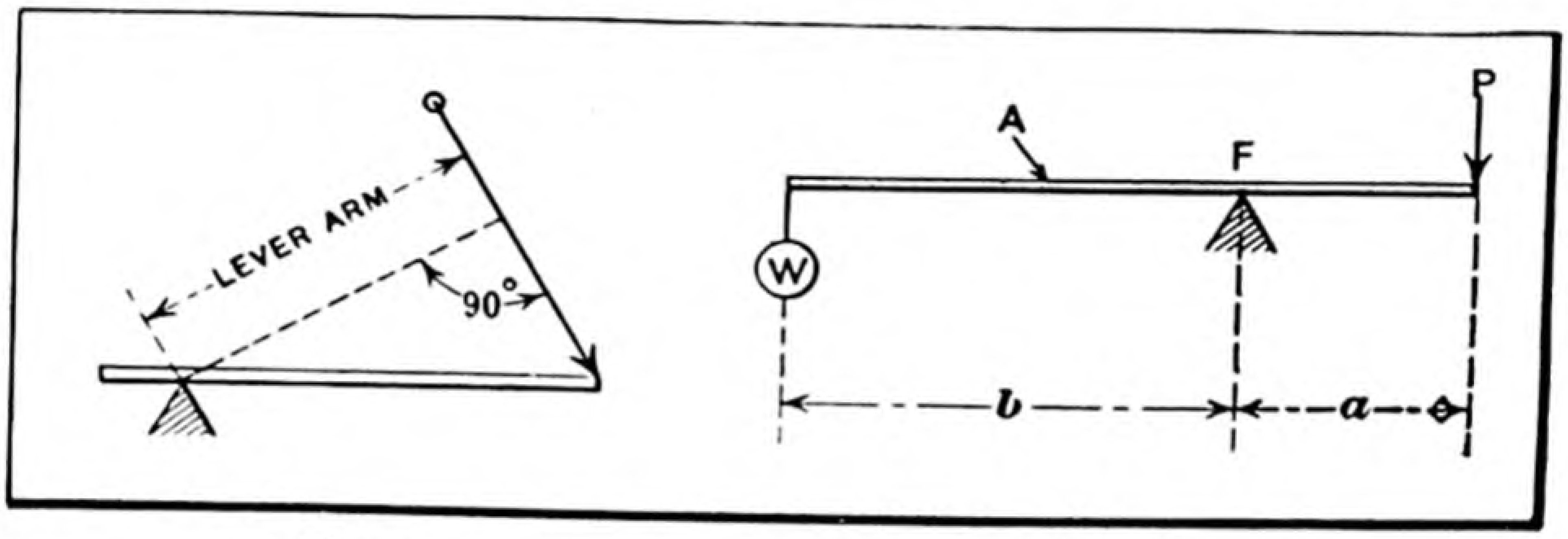


Fig. 1 Fig. 2

it in the opposite direction about the same fulcrum. Thus, in Fig. 2, in order that the lever *A* shall be in equilibrium, it is necessary that the weight *W* times its distance from *F* shall equal the force *P* times its distance from *F*, or that the moment of the force *P* equals the moment of the weight *W*:

$$P \times a = W \times b.$$

If the weight sustained by the lever equals 20 pounds, the distance *b* equals 5 inches, and the force *P* equals 2 pounds, then the distance *a* must equal 50 inches in order that equilibrium may exist.

$$2 \times 50 = 20 \times 5.$$

See also Compound Levers; and Rolling Levers.

LEWIS FORMULA. The method in most common use for determining the strength of spur gears is the one introduced by Wilfred Lewis and described by him in a paper read before the Engineer's Club of Philadelphia, October 15, 1892, and published in the proceedings of the club, January, 1893. The Lewis formula is directly applicable to cut gears and it will be found in engineering handbooks.

LEYDEN JAR. The Leyden jar or condenser is an electrical appliance devised for storing up small amounts of electrical energy in the early re-

searches into the nature of electricity. It consists in its simplest form of a thin glass jar partly coated inside and outside with tin foil. When the two metal surfaces are connected for a short time with the terminals of some source of electromotive force, the electrical energy is stored up in the condenser and can be removed in the form of an electrical discharge. Modern forms of Leyden jars are employed for the production of high-frequency electric currents used in wireless telegraphy. For this purpose, very large condensers are required, and, as the ordinary Leyden jar occupies too much space in comparison with its electrical capacity, the best form of condenser consists of a number of sheets of glass, each partly coated on both sides with tin foil. These plates are placed in a vessel filled with insulating oil. All the tin foils on one side of the glass plates are connected together, and so also are all the tin foils on the opposite side, in which manner a condenser of any required capacity may be constructed.

LIABILITY OF EMPLOYER. The liability of an employer for injuries sustained by an employe is based upon the well established law that an employer is not liable for the payment of damages for injuries sustained by an adult employe, if it is proved to the satisfaction of the Court that the workman was injured as a result of his own negligence. Where an employer knowingly hires a minor without his parent's consent and requires him to do dangerous work, in the performance of which the minor is injured, the employer may be liable, even though the minor's carelessness or negligence may have contributed to a great extent to the occurrence of the accident which caused the injury; but if it is shown to the satisfaction of the Court that the minor falsely stated his age and the employer believed he was of legal age, the employee may be relieved of liability for injuries sustained unless the injury was due to the employer's neglect.

LIANG. This is a Chinese measure of weight, legalized in 1908, equal to 37.30 grams or 576 grains.

LIFTING MAGNETS. See Magnets, Lifting.

LIFT OF WATER PUMPS. The atmospheric pressure, as shown by a barometer, is changing constantly. The normal pressure at sea level is approximately 14.7 pounds per square inch. A column of water approximately 2.31 feet high exerts a pressure of one pound per square inch. Hence with a normal atmospheric pressure of 14.7 pounds per square inch and a perfect vacuum in a pump chamber (assuming that a perfect vacuum were possible) the height of the lift would equal $14.7 \times 2.31 = 33.95$ feet, which is the maximum theoretical lift at sea level. The theoretical lift diminishes with an increase in altitude above sea level, because the higher the altitude, the less the atmospheric pressure. The theoretical lift for any altitude

may be determined by multiplying the barometric reading in inches by 1.132. For liquids other than water, first find the theoretical lift for water, and then divide it by the specific gravity of the liquid.

As it is not possible to obtain a perfect vacuum in the cylinder of a pump, because of mechanical imperfections and also because of air contained in the water and vapor given off by the water, the actual maximum height to which water can be lifted is less than the theoretical height of 33.95 feet; furthermore, if it were possible to produce a perfect vacuum, a pump would not lift water to the maximum theoretical height, because some energy is required to overcome frictional resistance in the pipe, lift the suction valves, and maintain a supply of water in the pump cylinder equal to the rate of displacement or discharge. With good pump construction, the actual lift for water is only about 0.82 of the maximum theoretical height, and the average pump when in good working order will lift water about 0.75 of the theoretical lift, or from 25 to 26 feet at sea level. As a general rule, it is advisable to limit the height of lift to about 0.60 per cent of the maximum theoretical lift, or to about 20 feet at sea level.

LIGHT INTENSITY STANDARD. See Candlepower; also Hefner Standard.

LIGHTNING ARRESTER. A lightning arrester is a device designed to protect an electric system against excessive voltages caused by abnormal atmospheric conditions. A lightning arrester should not be expected to protect against direct lightning strokes, as it would be impossible for the arrester to dissipate the enormous amount of power accompanying such discharges. There are many different types of lightning arresters, the selection of the proper type depending not only upon the voltage of the system but also on its capacity.

LIGHTNING CONDUCTOR. A lightning conductor is a metal rod or wire cable intended to carry off the electrical charge of lightning in order to protect buildings or structures. Power plant chimneys should always be provided with lightning conductors having copper points $\frac{3}{4}$ inch in diameter, 8 feet long, and with $1\frac{1}{2}$ inch platinum tips. Two points should be used as a minimum for chimneys less than five feet inside diameter, and for larger chimneys one point should be added for every two feet increase in diameter.

LIGHT WAVE AS LENGTH STANDARD. In 1907 the wave length of cadmium light, as determined by Benoit, Fabry, and Perot, was adopted by the International Union for Coöperation in Solar Research (now the International Astronomical Union) as the international standard for all spectroscopic work. Since that time many other wave lengths have been

determined, so that there are now available a very great number of secondary wave length standards accurately known in terms of cadmium waves.

The idea of using the wave length of light as a standard of length has been proposed by metrologists from time to time beginning even before Michelson's work. Michelson saw clearly the possibility of establishing the length of a meter bar at any future time by reference to light waves, if once the value of the wave length were determined, and pointed out the possibility of restoring the prototype meter if it should suffer loss or damage, and also the possibility of detecting any change in the standard meter bars. The possibility of such a control was also emphasized by Fabry, Perot, and Benoit who pointed out that the earlier proposals and laws for using a seconds pendulum or the earth's quadrant for these purposes do not fulfill modern requirements.

The relation between the meter and the wave length of cadmium light, as determined by Benoit, Fabry, and Perot, is as follows: 1 meter equals 1,553,164.13 wave lengths of red cadmium light. This wave length is based on standard conditions of temperature, pressure and humidity, and the number of waves per meter as given is probably correct to one part in 10,000,000, which means that the meter may be defined in terms of light waves with an accuracy of one part in 10,000,000.

LIGHT-WAVE MEASURING METHOD. Light is a form of wave motion. Different colors of light have different wave lengths ranging from 0.0000169 inch (the average length of violet waves) to 0.0000268 inch for red waves. Daylight contains all the colors and has an average wave length of approximately 0.00002 inch. Monochromatic light is light in which one wave length or color predominates. The following explanations assume a monochromatic light having a wave length of 0.00002 inch.

An optical flat is a practically flat transparent test surface. Unlike a lens, it has no magnifying power. Interference bands, which occur between the contacting surface of an optical flat and a flat or nearly flat reflecting surface, appear as merging colored bands or fringes in daylight; and as alternate in monochromatic light.

When a series of straight interference bands occurs between two flat contacting surfaces, there is always a wedge of air between them, contact being at one side only. The bands take a direction at right angles to the slope or direction of the wedge. The number of bands per inch indicates the steepness of the wedge, which increases in thickness from the point or side of contact at the rate of one-half wave length (0.00001 inch) per dark band. The pronounced light spot indicates the point of contact. The dark interference bands are not light waves, but simply show the points or spaces where the light waves reflected from one surface interfere with the waves reflected from the other surface. The light spaces show the point

of reinforcement. It is the dark interference bands that indicate the useful measuring unit of 0.00001 inch.

Straight parallel and evenly spaced bands indicate a flat surface, and curved and irregular bands indicate a curved or irregular surface. One of the earliest devices to be used in mechanics was the wedge. It is this elementary mechanical principle that is employed in comparing the length of two flat gage blocks, and also for measuring diameters of cylindrical plugs and balls. Two optical flats are used to form the wedge. The thickness of the wedge is fixed at one point by the thickness or length of a known standard gage block, and at another point by the diameter of the ball or cylindrical plug being measured. From the position, direction, and spacing of the interference bands, the slope of the wedge is found and, consequently, the exact amount that the ball or plug is larger or smaller than the standard is easily determined.

LIGHT-WEIGHT METALS. See Electron Metal; also Magnalium.

LIGNITE OR BROWN COAL. Lignite, also known as "brown coal," contains less than 50 per cent of carbon and over 50 per cent of volatile matter, and has a heating power per pound of combustible of from 11,000 to 13,500 B.T.U. Lignite may be divided into two classes: (1) Sub-bituminous coal, also known as lignite, black lignite, brown coal, lignitic coal, etc.; this kind resembles bituminous coal, is black and shiny, but disintegrates more rapidly when exposed to the air, and its heating value is not as high as that of bituminous coal; (2) lignite, also known as brown lignite or brown coal, is distinctly brown in color and has a woody structure. It contains from 30 to 40 per cent of moisture, and has a lower heating value than any of the other coals. It is, in fact, intermediate between coal and peat, and is fragile, splitting into small pieces when exposed to the air.

LIME SET. In blast-furnace operation a lime set is caused by a slip allowing a large amount of limestone to drop into the molten mass of metal, so that the slag becomes too thick to flow out of the furnace.

LIMIT. In every interchangeable mechanism there are certain maximum and minimum sizes for each part, between which the parts will function properly in conjunction with each other and outside of which they will not. These sizes are the absolute limits of the parts. The established limits are the maximum and minimum dimensions specified on the drawings. The words *limit* and *tolerence* are often used interchangeably but tolerance represents the difference between the minimum and maximum limits. See Tolerance.

LIMIT GAGES. With the modern system of interchangeable manufacture, machine parts are made to a definite size within certain limits

which are varied according to the accuracy required, which, in turn, depends upon the nature of the work. In order to insure having all parts of a given size or class within the prescribed limit, so that they can readily be assembled without extra and unnecessary fitting, what are known as *limit gages* are used. One form of limit gage for external measurement is double-ended and has a " go " end and a " not go " end; that is, when the work is reduced to the correct size, one end of the gage will pass over it, but not the other end. Limit gages are very generally used for the final inspection of machine parts, as well as for testing sizes during the machining process. They are superior to the micrometer for many classes of inspection work, because the adjustment and reading necessary with a micrometer not only requires more time but often results in slight variations of measurement, especially when the readings are taken by different workmen.

LINCOLN TYPE MILLING MACHINE. See Milling Machines, Lincoln Type.

LINE-DROP COMPENSATOR. This is a device which is employed for modifying the reading of voltmeters used in electric power stations, without using a pressure wire from the distributing point, so that the reading corresponds to the pressure at that point. Line-drop compensators consist of a variable resistance and reactance coil, so connected and adjusted as to allow for the resistance and reactance of the line for which they are used.

LINE OF ACTION IN GEARING. The term " line of action " as applied to gearing means the line that would be described by the point of contact of two gear teeth from the time they come into contact until they separate. Gear teeth having a form based on a system of curves such as the involute and cycloidal systems have a fixed line of action and the point of contact of any two gears of an interchangeable system, that mesh correctly, must follow this fixed line.

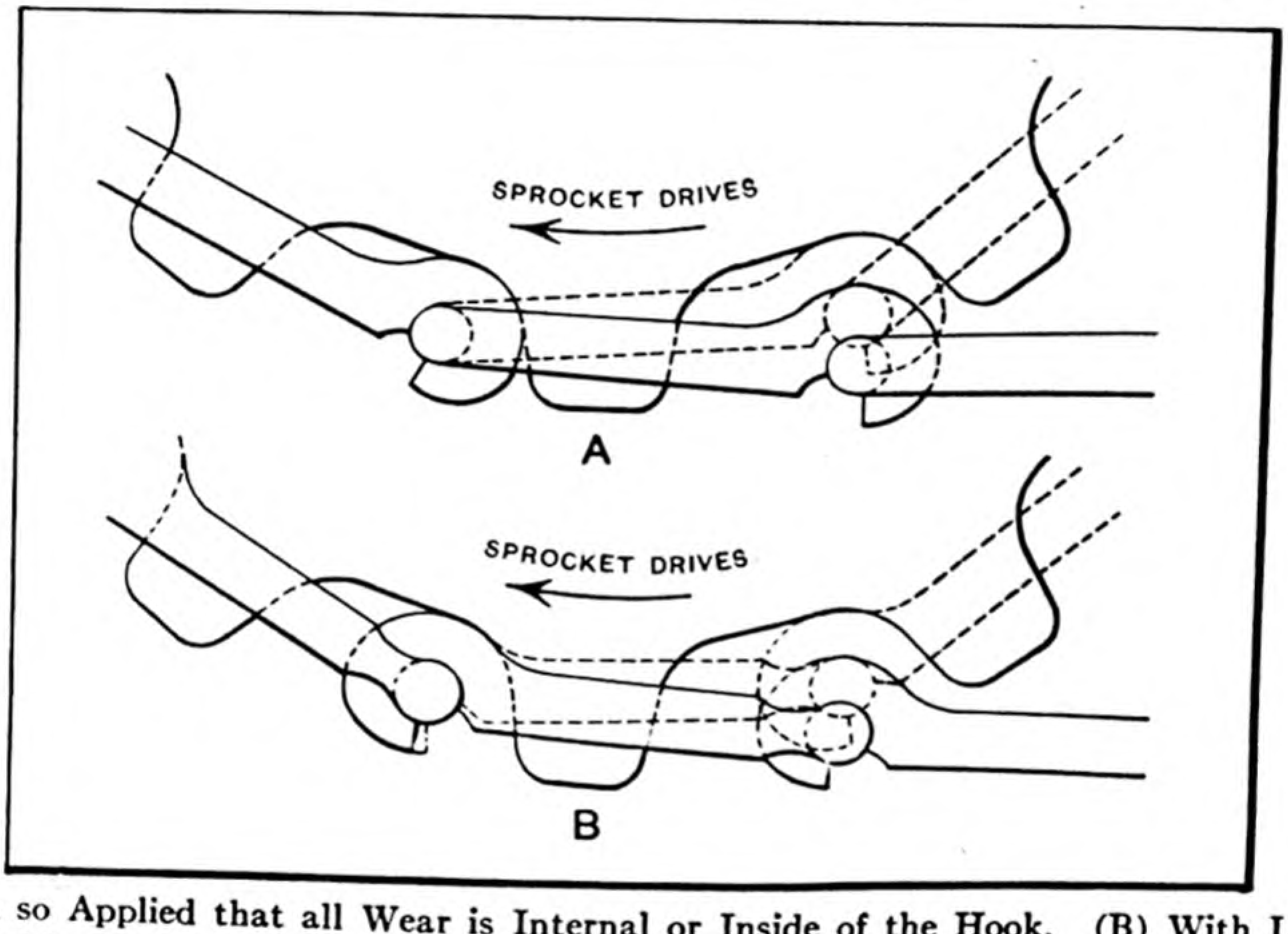
LINEOMETER. The chain lineometer is an instrument by means of which the length of a sprocket or driving chain can be determined quickly without making a calculation.

LINE-SHAFTING. Long continuous lines of shafting for transmitting and distributing power in shops and factories are known as *line-shafting.* In general, shafting up to three inches in diameter is almost always made from cold-rolled steel. This shafting is true and straight and needs no turning, but if several keyways are cut in the shaft, it must, as a rule, be straightened afterwards, as the cutting of the keyways relieves the tension on the surface of the shaft due to the cold-rolling process. Sizes of shafting from three to five inches in diameter may either be cold-rolled or turned, although turning is more common and is always employed for sizes of shaft-

ing larger than five inches. In calculating line-shafts, the strength to resist torsion, as well as the stiffness to resist angular deflection and deflection between bearings, must be considered. Large diameter shafts of no considerable length need be calculated for strength only; long, slender shafts must also be calculated for stiffness.

LINK. A link is a surveyor's length measure, equal to 7.92 inches.

LINK-BELT. The chain known as a "detachable link-belt" or link-chain was invented by Wm. D. Ewart, in 1873. This type of chain was applied originally to harvesting machinery but is now used for many different



(A) Link so Applied that all Wear is Internal or Inside of the Hook. (B) With Link in this Position there is Wear on the Outside and Inside of the Hook and on the Sprocket

classes of transmission service, and especially for all kinds of elevating and conveying machinery. The chain is made of refined malleable iron, and the links are connected directly by hook-shaped ends, each link having a hook at one end which engages the plain end of the adjacent hook. The sizes of detachable link-belting are designated by numbers. These chains are made in a number of different types or patterns suitable for different purposes. Some of these patterns are adapted for conveyor chains but are not suitable for power transmission, and *vice versa*.

Whenever possible, a link-belt should run with the back of the coupling hook to the sprocket wheel. The action is considered good when all of the bending takes place at the joint of the chain, as shown at *A*. (See illustration.) The dotted lines show the position of the link after bending, and the action is such that all of the wear is internal or on the inside of

the hook. The action is considered bad when in bending the link rubs on the sprocket, thus wearing both the sprocket and the hook, as indicated at *B*.

LINK-BELT SPROCKETS. See Sprockets, Link-chain.

LINK FUSE. The link fuse was the earliest type of fuse for electrical circuits and is still used, to some extent. It consists of a piece of wire or strip of some fusible metal, such as lead alloy, soldered to copper terminals that fit under the binding screws in the contact blocks.

LINOTYPE METAL. Linotype metal, used for casting the slugs of type on linotype machines, is composed of an alloy of lead, tin, and antimony. The proportions vary somewhat, but, as a general average, the composition consists of 85 per cent of lead, 3 per cent of tin, and 12 per cent of antimony. Antimony is used in this metal because it has the quality of making the alloy expand upon cooling, thus filling the mold completely and making the type sharp and distinct. An alloy consisting of 82 per cent of lead, 5 per cent of tin, and 13 per cent of antimony is used to a great extent for newspaper work, and is said to work equally well for linotype, monotype, and stereotype.

LIQUID AIR. See Liquid Oxygen.

LIQUID CONTROLLER. This is an electric motor controller which may be either of the hand-operated non-automatic type or power operated. The hand-operated controller is used for small motors and consists simply of electrodes immersed in a solution of soda and water, the resistance being changed by elevating or lowering the plates in the solution, thus changing the immersed area of the plates. This controller is seldom used. The power-operated type is based upon the same principle of action, but is semi-automatic in its action and has been extensively used for large motors, 400 horsepower and above.

LIQUID GLUE. See Glues for Wood.

LIQUID MEASURE. 1 U. S. gallon = 0.1337 cubic foot = 231 cubic inches = 4 quarts = 8 pints; 1 quart = 2 pints = 8 gills; 1 pint = 4 gills; 1 British Imperial gallon = 1.2003 U. S. gallon = 277.27 cubic inches; 1 cubic foot = 7.48 U. S. gallons.

LIQUID OXYGEN. Oxygen was first liquefied by the French scientist, Louis-Paul Cailletet. Liquid oxygen is air reduced to liquid form, from which, in the process of powerful compression, the nitrogen is distilled off. In the alternating process of compression and expansion through which it is produced, it reaches a temperature of 269.5 degrees Fahrenheit, below Zero. In its quiescent form liquid oxygen instantly freezes all substances

immersed in it. Poured on ice, it vigorously boils, so much colder is it than the ice itself.

LIQUID OXYGEN EXPLOSIVE. Liquid oxygen explosive, or L.O.X. as it has become known, is made by mixing very finely divided carbon, in the form of lampblack or carbon black, with the liquid oxygen which is highly concentrated oxygen. The association of the carbon and the oxygen is so intimate that when combustion is started due to a fuse or detonator, the carbon instantaneously burns and creates a large volume of high temperature carbon dioxide gas. At the moment of combustion, or explosion, the temperature of liquid oxygen jumps from 269.5 degrees below Zero to 5,603 degrees above, a variation of 5,872 degrees. The shattering force of this combustion is sufficient to rend huge strata of deeply imbedded rock. The practicability of liquid oxygen as an explosive has been put to test by the United States Bureau of Mines, in collaboration with scientists engaged in its development. It has been found particularly advantageous in blasting rock in quarries or in other open rock formations. One pound of liquid oxygen, together with one-fifth of a pound of carbon, with which it is packed in the cartridge, will do the work of one pound of 40 per cent dynamite. The safety of blasting with L.O.X. is one of its characteristics, recognized officially by the Bureau of Mines. Danger from accidental explosion is much reduced. Its cartridges cannot be set off except by a very severe shock such as the impact of a bullet.

LIQUID RHEOSTAT. Same as Liquid Controller.

LITHARGE. Litharge, or lead monoxide, is formed by heating lead intensely for several hours. It is yellowish red, very heavy, and grinds in 9 per cent of oil. A strong cement which is oil-proof, waterproof, and acid-proof, consists of a stiff paste of glycerin and litharge. These form a chemical combination which sets in a few minutes. If a little water is added, it sets more slowly, which is often an advantage. This cement is mixed when required for use. A handy cement for stopping leaks, etc., and which can be used for cementing glass, brass, etc., is made by mixing equal parts of litharge, commercial glycerin and Portland cement. This cement will harden under water and will withstand hydrocarbon vapors.

LITHOLITE. Litholite is an electrical insulating material made from paper pulp into sheets and pressed into any desired form. Litholite is tough, but inflammable. It is softened by the action of sulphuric acid and distilled water, and is reduced to a pulp if immersed in caustic soda. Approximately 20,000 volts are required to puncture a sheet about $\frac{3}{16}$ inch thick. Litholite is used for tubing, bushings, washers, and commutator rings.

LITHOPONE. Lithopone is produced by mixing a solution of zinc sulphate with one of barium sulphide, and is used for the making of paints for the protection of iron and steel against corrosion. It is the whitest pigment known, and is widely used in high-grade enamel. It has a specific gravity of 4.25 and grinds in 13 per cent of oil.

LIVE CENTER. A live center is a center on which work is held in a machine tool and which revolves with the work. In a lathe, the center mounted in the revolving or headstock spindle is the live center.

LIVE WIRE. The term " live wire " is commonly applied to an electrical conductor charged with electricity.

LLOYD & LLOYD THREAD. The Lloyd & Lloyd screw thread is the same as the regular Whitworth screw thread in which the sides of the thread form an angle of 55 degrees with one another. The top and bottom of the thread are rounded.

LOAD-AND-FIRE MECHANISM. When a reversal of motion of a machine member depends upon the action of a clutch which may be shifted from one gear to another revolving in an opposite direction, it is essential to operate the clutch rapidly and to secure a full engagement of the clutch teeth. One form of control may be defined as the swinging-latch type and another as the beveled-plunger type. The general principle of operation is the same in each case, and is as follows: When the work table, or whatever part is to be reversed, approaches the end of its stroke, a spring is compressed, and then a latch or trip allows this compressed spring to suddenly and rapidly throw the reversing clutch from one gear to the other. Reversing mechanisms of this general design are often called the " load-and-fire " type, because the spring is first loaded or compressed and then tripped to secure a rapid movement of the clutch and a reversal of motion at a predetermined point within close limits. Provision should also be made against disengagement of the clutch as the result of vibrations incident to the operation of the machine.

LOADED GRINDING WHEEL. A grinding wheel is " loaded " when the pores or interstices between the cutting particles are partly or entirely clogged with the material being ground. Loading prevents the wheel from cutting and causes excessive heat to be generated. If a wheel becomes loaded, the bond may be too hard or the speed too slow. The remedy for loading is to increase the speed or use a softer wheel.

LOAD FACTOR. The load factor of a machine, plant, or system is the ratio of the average power to the maximum power during a certain period of time. The average power is taken over a certain period of time, such

as a day, a month, or a year, and the maximum is taken as the average over a short interval of maximum load within that period. In each case, the interval of maximum load and the period over which the average is taken should be definitely specified, such as a "half-hour monthly" load factor. The proper interval and period are usually dependent upon local conditions and upon the purpose for which the load factor is to be used.

LOAM CORE. A loam core is a large core for castings made from loam on a cast-iron core-barrel so that the core is hollow. If made solid, it would be very heavy and difficult to handle. In making a loam core, the core-barrel is first wound with rope and a loam mixture is applied in a comparatively soft state and smoothed out over the surface, the barrel being turned during this process, so that the core is formed to a circular section at all points.

LOCAL HARDENING. Steel parts may be hardened locally, instead of throughout, in order to provide a hard wear-resisting surface for one section and at the same time secure greater strength or toughness of the part as a whole, by leaving the remainder soft. Local hardening may also be done primarily, to prevent excessive distortion which might result from complete hardening. The local hardening of tool steel requires some method of preventing the sudden cooling of the parts that are to remain soft, and local hardening of case-hardened steel requires some method of preventing carburization wherever the surfaces are to remain soft. A compound having the trade name "Localhard" (formerly Enamelite No. 2) provides a chill-resisting coating for tool steel for protecting the part that is to remain soft from the sudden cooling action of the quenching bath. This preparation liberates hydrogen gas (the greatest known non-conductor) when the hot steel is plunged into water so that the steel thus protected retains its heat long enough to prevent sudden cooling and consequently remains soft. This protective coating automatically separates from the steel which is left clean.

Local Carburi ing. In carburizing parts preparatory to casehardening there are several ways of preventing portions of the work from being exposed to the carbon-carrying gases. A satisfactory method of local carburizing, when the volume of the work warrants it, is the copper-plating method. It is well known that it is impossible to harden copper by heat-treatment, because carbon is the chief hardening element in metals, and there is no affinity between copper and carbon. The copper is plated on the work by the electroplating process. A coating of copper sulphate is unsatisfactory, as there is no bond between the steel and the copper. In order to eliminate mechanical removal of the copper, japanning of the surface desired to be carburized is often resorted to before copper-plating. After baking the japan on,

the work is plated, but the copper does not adhere to the japanned portion. The japan burns off in the carburizing process, and the steel formerly covered by the japan becomes carburized.

Localcase (formerly called Enamelite No. 1) is a substitute for copper plating in local casehardening. The surface or surfaces that are to resist carburization and remain soft are covered with Localcase. This compound is also used to resist the oxidation of metals while heating.

Another method is to cover the sections that are to be kept free from an increase in carbon with fireclay mixed with water to the consistency of putty, then dried by moderately slow heat, and finally packed in the pots with a carburizer in the ordinary manner.

A metal protecting sleeve is practical where the form of the work warrants its use. This method consists of slipping a sleeve or collar over the part required to be free from an increase of carbon. The sleeve is either a push or loose fit, and if the latter, it can be wired in place.

Asbestos is often used in local carburizing by wrapping it around the section desired to be kept free from an increase in carbon and binding it in place with bundling wire.

A thin paste of water glass (sodium silicate) and kaolin (a fine grade of clay) may be painted on sections of the work that are to be kept free from an increase in carbon. Used sand-blast sand in a finely divided state is often mixed with this. This mixture is dried on the work by air, after which the work is packed in pots in the regular way

LOCK-JOINT, CONVERSE. See Converse Lock-joint.

LOCK-NUT. A lock-nut, also known as a check-nut, is a supplementary nut screwed down upon another in order to prevent it from becoming loose, due to the vibration of the machinery onto which the nut is attached. A *nut-lock* is a device for fastening a nut in place so that it will not become loose. A great variety of means have been devised for locking a nut in place so as to prevent accidental loosening of the parts held together by the nut on its bolt.

LOCK-NUT PIPE THREAD. The lock-nut pipe thread is a straight thread of the largest diameter which can be cut on a pipe. Its form is identical with that of the American or Briggs standard taper pipe thread. In general, " Go " gages only are required. These consist of a straight-threaded plug representing the minimum female lock-nut thread, and a straight-threaded ring representing the maximum male lock-nut thread. This thread is used only to hold parts together, or to retain a collar on the pipe. It is never used where a tight threaded joint is required.

LOCOMOTIVE BOOSTER. See Booster on Locomotive.

LOCOMOTIVE CRANE. This is a pillar crane mounted upon wheels and arranged to travel longitudinally upon rails. It is provided with a steam engine capable of propelling it along the rails and with steam power for hoisting and moving the load.

LOCOMOTIVE DEVELOPMENT. The first steam locomotive which ever ran on rails was built in 1804 by Richard Trevithick, an Englishman, and the first one to be used on a commercial basis was built by Matthew Murray, another Englishman. In 1811, Blenkinsop of Leeds, had several locomotives built by Murray in order to operate a railway extending from Middletown Colliers to Leeds, a distance of three and one-half miles. Trevithick's impracticable design had a single cylinder only, but Murray used two cylinders which were utilized in driving the same shaft on which cranks were set at right angles — an important arrangement common to all modern locomotives. A cog-wheel, or gear, meshing with a continuous rack laid along the road-bed was employed. These locomotives were used daily for years and were examined by George Stephenson when he began his work on locomotive development. Several years after the construction of Murray's locomotives Hedley and Stephenson demonstrated that the gear and rack method of propulsion was unnecessary, and that the frictional resistance of smooth drivers would supply adequate tractive power. Stephenson's name will always be associated with locomotive development owing to his accomplishments in perfecting the locomotive and in establishing it on a commercial basis. His first locomotive was tried on the Killingworth Railway in 1814. The first locomotive to be used in the United States was imported from England in 1829.

LOCOMOTIVE LIFE. A survey to determine the length of life of locomotives on American railroads, showed that the average age of locomotives dismantled or recommended for dismantling on the Pennyslvania Railroad is 29.4 years, and on the Chicago, Milwaukee & St. Paul, 35.5 years, while most of the other railroads vary between these figures. In general, the average retiring age of locomotives is approximately from 30 to 33 years. On the Louisville & Nashville Railroad nearly 25 per cent of the engines, at the present time, have given 30 years' service or over.

LOCOMOTIVE, OIL-ELECTRIC. The oil-electric locomotive is so named because oil engines are used as the primary source of power and drive electric generators which supply current for operating motors geared to the driving wheels. Such locomotives are used in the freight-handling yards of steel plants, rolling mills, or other industrial plants for shipping loaded and unloaded cars, etc., and for similar classes of service.

LOCOMOTIVE PISTON-VALVE. See Piston-valve.

LOCOMOTIVE TAPER REAMERS. Taper reamers for locomotive work are generally made in two styles, with square and with taper shanks. The taper of these reamers, as used in different railroad shops, varies, but the commonly accepted standard is $\frac{1}{16}$ inch per foot. The fluted part of taper-shank reamers is made the same as for reamers with square shank, the over-all length depending upon the Morse taper shank used.

LOCOMOTIVE TRACTIVE FORCE. See Tractive Force.

LODESTONE. The most highly magnetic substances are iron and steel. Nickel and cobalt are also magnetic, but in a less degree. The name "magnet" has been derived from that of Magnesia, a town in Asia Minor, where an iron ore was found in early days which had the power of attracting iron. This ore is known as *magnetite* and consists of about 72 per cent, by weight, of iron and 28 per cent of oxygen, the chemical formula being Fe_3O_4. The ore possessing this magnetic property is also known as *lodestone.* If a bar of hardened steel is rubbed with a piece of lodestone, it will acquire magnetic properties similar to those of the lodestone itself.

LOG$_e$. This is an abbreviation designating natural, hyperbolic or Napierian logarithms.

LOGARITHMIC PAPER. Logarithmic paper is a cross-section ruled paper used for plotting diagrams, in which the spacing between the lines is arranged according to the logarithmic scale, the object of this being to obtain greater simplicity in the plotting of equations containing exponents, in diagrammatical form. The cross-section paper on the market is ruled in the following ways: 1. Divided horizontally and vertically into centimeters and millimeters. 2. Divided horizontally and vertically into inches and eighths or tenths of an inch. 3. Divided horizontally into inches and tenths, and vertically, logarithmic, from 1 to 10. 4. Divided both ways, logarithmic, from 1 to 10. 5. Divided both ways, logarithmic, from 1 to 100.

In science and engineering, the law of variation in quantities is usually expressed as an equation. When this equation is of the first degree, it is graphically plotted on cross-section paper as a straight line. When the variable enters in any other power or root than the first, a curve results. On ordinary square-sectioned paper, plotting a curve is very laborious, as a great many points must be found in order to obtain the shape of the curve. In tracing a curve through the plotted points, it is difficult to obtain a draftsman's irregular curve which will "fit," and, as a result, the curve as drawn is only correct at the plotted points. When the equation has the form $x = ay^m$, in which the exponent m is of any power or any root, logarithmic paper has a distinct advantage over ordinary square-sectioned paper.

As its name implies, it is divided logarithmically, that is, the distances of the abscissas and the ordinates from the origin are proportional to the logarithms of the numbers instead of to the numbers themselves. Where a great many diagrams are to be made, logarithmic paper is a time-saver. It may be used for purposes of calculation in many ways which will suggest themselves to the engineer. Among the more common uses to which it may be put are the following: Powers and roots of any and all indices; bending moment, shearing stress, or deflection of beams in terms of span or load; moments of inertia and radii of gyration in terms of a linear dimension: circumferences and areas of circles in terms of their diameters; sizes of bars, struts, shafts, etc., in terms of a linear dimension; hydraulic equations, etc.

LOGARITHMS. The purpose of logarithms is to facilitate and shorten calculations involving multiplication, division, the extraction of roots, and the obtaining of powers of numbers. In the common or Briggs system of logarithms, the *base* of the logarithms is 10; that is, the logarithm is the *exponent* that would be affixed to 10 in order to give the number corresponding to the logarithm. For example $\log 20 = 1.30103$, which is the same as to say that $10^{1.30103} = 20$. $\text{Log } 100 = 2$, and $10^2 = 100$. As $10^1 = 10$, the logarithm of $10 = 1$. It is known from algebra that $10^0 = 1$; hence the logarithm of $1 = 0$. While most of the tables of logarithms are given to five decimals, it should be understood that the logarithm of a number can be calculated with any degree of accuracy; hence, there are tables giving the logarithms with as many as seven decimal places, and some, used for very accurate scientific investigations, giving as many as ten or more decimals. Tables of logarithms and information about their application will be found in Machinery's Handbook.

LOHMANNIZING. The protection of iron and steel has generally been effected by means of zinc-coating processes. The process of "Lohmannizing," invented by H. J. Lohmann, differs in that it is not restricted to the application of zinc coatings, but may be used for coatings of zinc, lead, and tin in varying proportions to suit the requirements of each case.

LOOM BOLT. This is a bolt having an oval head beneath which the bolt is square for a short distance. The other end of the bolt is threaded for a distance equal to about twice its diameter, for a square nut.

LOW BRASS. So-called "low" brasses which are especially suitable for hot rolling, contain from 37 to 45 per cent of zinc, the remainder being copper. Other low brasses contain as little as 20 per cent of zinc.

LOW-CARBON STEEL. This term is applied to steel containing generally from 0.10 to 0.25 per cent of carbon, but it sometimes includes all

steels up to about 0.60 per cent of carbon. Low-carbon steel is used for structural purposes and for machine building. It does not contain enough carbon to harden appreciably if heated and quenched, but may be case-hardened by first carburizing the surface.

LÖWENHERZ THREAD. The Löwenherz thread is intended for the fine screws of instruments and is based on the metric system. It has been adopted by the Bureau of Standards as there has been a lack of uniformity in the screws applied to American-made instruments. The Löwenherz thread has flats at the top and bottom the same as the U. S. standard form, but the angle is 53 degrees 8 minutes. The depth equals 0.75 × the pitch, and the width of the flats at the top and bottom is equal to 0.125 × the pitch. This screw thread is used extensively for the fine threads of measuring instruments, optical apparatus, etc., especially in Germany.

LOWMOOR IRON. Lowmoor iron is the name used for the best grade of wrought iron made in England. Its chief characteristics are as follows: Wrought-iron bars, 1 square inch in cross-section and less, have a tensile strength of 50,000 pounds per square inch and an elongation in ten inches of 26 per cent. For bars having a cross-section up to 8 square inches, the tensile strength is about 48,000 pounds per square inch, with an elongation of from 22 to 24 per cent in ten inches. For bars larger than 8 square inches in cross-section, the tensile strength may be assumed as 46,000 pounds per square inch, with an elongation of 21 per cent in ten inches. These tensile strengths relate to tests *with* the grain; *across* the grain, the strength of Lowmoor iron may be taken as 42,000 pounds per square inch, and the elongation in eight inches as 12 per cent.

LOW-VOLTAGE TRIP. A low-voltage trip is an arrangement used in connection with a circuit-breaker for tripping when the voltage of the circuit falls off to a predetermined amount; in practice this is usually about one-half of the full line-voltage.

LOZENGE CHISEL. Same as Diamond Chisel.

LUBRICANTS. Lubricating oils are obtained chiefly from petroleum which has had the lighter components (naptha and kerosene) removed by distillation. The residue after such distillation may be used directly as a lubricant or it may be separated into various fractions by distillation. A variety of lubricants having special properties, such as viscosity, flash point, cold test, and specific gravity, may be obtained by removing some of the fractions or by mixing others. The separate fractions may be further refined to remove odor, resinous elements, etc., as well as to secure the desired color.

Paraffin- and Asphalt-base Oils. — The comparative value of paraffin-

and asphalt-base oils is often discussed, though most lubricating oils come from stocks containing both bases, and it is doubtful if the average engineer could tell which he is using, if there were no label. Paraffin oils stand warming slightly better than asphalt-base oils, but freeze solid when subjected to temperatures at which the latter remain liquid and capable of giving good service. There is no perceptible difference in their chemical stability, both breaking up and depositing heavy tars at about the same temperatures. The most stable hydrocarbons, such as kerosene, benzol and benzol-oils are not good lubricants, while the least stable, or heavier hydrocarbons are the best lubricants. It is claimed by several of our best chemists that the quality of oiliness or slipperiness comes from the very fact that the oil is not stable, but composed of unstable or unsaturated compounds. Therefore an oil cannot be both stable and a good lubricant, which is apparent from the fact that no hydrocarbon whose composition is definitely known to be stable is a good lubricant. This is the reason why it is difficult to obtain good lubricants for high temperatures. An oil that will stand the temperature is not as "oily" as some of the less stable oils used at lower temperatures.

Mineral Oils. — Mineral oils are classed commercially as "pale" and "dark." The pale oils are somewhat transparent and are tinged with a variety of yellow and red shades. The dark oils are opaque and are either greenish- or brownish-black. The specific gravity of mineral oils usually varies from about 0.860 to 0.940, and the flashing point, from 300 to 600 degrees F. The oils obtained from petroleum have a much wider range of viscosity than the "fixed oils." The thinnest are more fluid than sperm oil, and the thickest more viscous than castor oil. The shale lubricating oils are of low viscosity.

Blended Oils. — Mineral oils possess valuable properties which are conferred upon other lubricants with which they are mixed; as they are also a great deal cheaper than good fixed oils, blended or mixed oils are commonly used. The percentage of mineral oil that should be added varies according to the load, speed, etc., because many mineral lubricants are deficient in the property known as "oiliness" and can seldom be used pure, except when the bearing is kept flooded with oil by bath, ring, or forced lubrication.

Fixed Oils and Fats. — Fixed oils are so named because they are not volatile without decomposition. They are obtained from the seeds or fruits of plants and the tissues of animals. All fixed oils become fats at low temperatures and, inversely, all fats become oils at 150 degrees F. The most common lubricants among animal oils are tallow, lard, neat's foot and sperm oil, and among vegetable oils, olive, rape, and castor oil. Ordinarily, animal oils are either colorless or yellow, whereas vegetable

oils have various shades of yellow and green. The specific gravity of fixed oils varies from about 0.879 to 0.968 at 60 degrees F. Sperm oil has the lowest viscosity and castor oil the highest.

LUBRICANTS, APPLICATIONS. A mixture of mineral oil and from 10 to 20 per cent of neutral animal or vegetable oil is suitable for bearings of *machine tools*, *shafting*, and all machinery of medium weight and speed. Animal oils are usually preferable to vegetable, as they are less liable to gum. The heavier the machine and the slower the speed, the greater the viscosity required. For *generators* and *motors* with bath or ring lubrication, use mineral oil (preferably pure) having from two-thirds to about three times the viscosity of rape oil at 60 degrees F., depending upon the size, weight, and speed of the machine.

For *light, delicate machinery* running at fairly high speeds, use mineral lubricating oil having about the same viscosity as sperm oil, and preferably mixed with from 10 to 20 per cent of sperm oil. For *pneumatic hammers*, use a good quality of light mineral oil, as a heavy oil tends to clog the parts. The ring spindles of *textile machinery*, running in an oil bath at speeds as high as 10,000 revolutions per minute, should be lubricated with a mineral oil of low viscosity not exceeding that of sperm oil at 60 degrees F. For *turbine bearings* having forced or circulating-pump lubrication, use pure mineral oil having a viscosity of from one to five times that of refined rape oil at 60 degrees F., depending upon the bearing pressure, speed, and temperature conditions. For *high-speed engine bearings* having forced lubrication, use pure mineral oil of about twice the viscosity of rape oil at 60 degrees F.

For *steam engine cylinders*, use heavy mineral cylinder oils mixed with from 5 to 25 per cent of rape or other fixed oil, the proportion of the latter being reduced as low as possible without impairing the lubricating quality. Sometimes pure mineral oil must be used in the cylinders of marine and other engines provided with surface condensers, to prevent fixed oils from entering the boiler. Vegetable and animal oils are unsuitable for cylinder lubrication, because, when subjected to high temperatures, they undergo a chemical change, resulting in the formation of free, fatty acids which may cause serious corrosion. Fatty oils, however, when mixed with mineral oils in quantities not exceeding from 5 to 20 per cent, do not seem to produce these objectionable results.

For *locomotive axles*, use mineral oil having from two to four times the viscosity of rape oil at 60 degrees F., mixed with refined rape oil in the proportion of three parts of mineral to one part of rape. For very *heavy locomotives*, especially in warm climates, it is desirable to increase the viscosity of the mixture by adding some good mineral cylinder oil. For *bear-*

ings working in hot places, use mineral oil to which is added from 20 to 33 per cent of blown or thickened vegetable oil (usually rape). For *gas engine cylinders*, a mixture of 90 per cent of mineral oil and 10 per cent of neutral fixed oil is largely used. The viscosity is about the same as that of rape oil at 60 degrees F. As carbonaceous deposits are liable to form in the cylinder by partial combustion of the lubricant, especially when used in excess, the mineral oil selected should have undergone very careful rectification, and have little tendency to decompose and deposit carbon when heated. It should also be an oil of low volatility, not being affected appreciably by evaporation at working temperatures.

Lubricants for Ball Bearings. — Ball bearings require lubrication and should never be run dry. The actual lubricating property of the lubricant used is not as important as its freedom from acid and its effectiveness as a preventative of rust. Mineral oil should be used instead of vegetable oils, such as castor, cotton-seed, rape, and linseed oils, which tend to develop acid and become gummy and rancid. Animal oils are objectionable for the same reasons. A mixture of vaseline and vaseline oil, or a good mineral oil is recommended.

In general, greases are recommended for speeds up to 2000 or 2500 revolutions per minute. When a high speed and resulting increase in temperature causes the grease to thin out, oil should be substituted. Ordinarily, grease is considered preferable because it can be more easily retained in the bearing case; but from any other point of view, oil is preferable. A grease should be used that does not contain free alkali, as the latter will pit or etch the polished steel surfaces the same as acids in oils. The specifications for a good ball-bearing grease would be as follows: A pure mineral oil, free from acid, alkali, or filler, which contains no substance that will act as an obstruction to the free movement of the balls or that will become rancid with age; and which is of such a consistency that it will be easily retained in the housing; the grease should not melt below 250 degrees F.

LUBRICATING SYSTEMS. Machine bearings are lubricated by various devices ranging from simple oil holes or cups to elaborate systems. The selection of a method depends upon such factors as speed, bearing pressure, and the importance of safeguarding against lubrication failure. The methods of feeding lubricants include the simple oil-hole, fed from a can, with no means of retaining a supply; the oil-cup with forced feed, obtained by screwing down a cap or plunger; the siphon cup with a wick feeding continually by capillary attraction; the grease-cup device with constant feed by spring pressure; the distributing box system with pipes and control taps to admit certain quantities of oil to the leading-out pipes; the needle lubricator in which the feed is produced by the vibration caused by the

rotation of the shaft; the oil-well or reservoir which is filled to a definite depth, and serves to lubricate by wicks, etc., or by the splash method for a long period; the force-pump which delivers a large amount of oil to one or several locations.

Lubrication by Felt Pads. — Felt pads for distribution of lubricant may either be used alone, or in combination with grooves in the bushing or on the shaft. The felt not only insures a supply of oil on every part of the journal that it touches, but it filters the oil as well, and prevents the passing of grit or particles of metal. The pads are fitted into slots cut in boxes or bushings, and either dip into a well, or are simply fed through holes by a cam, or from some type of lubricator.

Use of Wicking. — When wicking is used to supply bearings the piece of wick leads from the oil reservoir to the bearing surface; and the oil feeds up due to capillary attraction. This is a very elastic principle, and possesses two main advantages. One is that the oil is filtered and, consequently, no dirt is transmitted by the wick; the other, that a feed can be procured from a well or gear-box not necessarily situated close to the bearing.

Ring Oiling. — A system most extensively employed for spindles and shafts is the ring-oiling method, which insures a larger flow than is caused by the pad device. It is used in conjunction with a reservoir for each bearing, or with a reservoir or box common to several bearings. The ring (or an endless chain) is hung loosely on the spindle, and revolves at a slow rate, thus bringing up oil from a well below the bearing.

Large rings have a smaller area in contact with the shaft than have smaller rings and they also have a tendency to assume a position oblique to the shaft and to swing laterally; consequently, the diameter of the ring should not be too large. Chain oiling offers many advantages over ring oiling, but the cheapness of rings and the fact that they give satisfactory service, generally, appears to be sufficient testimony to the efficiency of rings. Some makers of ring-oiling bearings make the rings below five inches in diameter from seamless brass tubing; the only objection to this material is that a tube is occasionally found that is eccentric enough to prevent satisfactory action. If the ring is very slightly out of balance, it will not move properly and fails to carry the oil to the bearing in a satisfactory manner. See also Oil-ring Design.

Oil Baths. — Submerged lubrication, that is by running parts in a bath of oil or grease which they continually stir up and spread over themselves, exists in many forms. In the oil bath as correctly arranged, there is never any lack of lubricant and the chief care is to see that no sediment is thrown up, or that any parts are shielded from the spread of oil.

Oil Circulated by Pumps. — Pump systems embody many arrangements of a varied character for the thorough distribution of the lubricant. In

the most complete gear-boxes, and in some machines — notably all-geared milling machines — the same supply is utilized to flood the gears and bearings, being pumped up from the well at the base and falling from a perforated pipe in cascades onto the gears, while suitably arranged pipes conduct it into the bearings.

Elevated Oil Tanks. — In very large machines, when a considerable quantity of oil has to be flooded through bearings and over surfaces, a head is sometimes obtained by the use of an elevated tank, from which pipes lead down to the various grooves or passages. The pump then replenishes the tank at the required rate, the oil being filtered before returning.

Forced-feed Lubrication. — If bearing pressures and speeds are high it may be desirable, if not necessary, to force the lubricant into the bearing under pressure. The pressures for horizontal bearings ordinarily range from 15 to 30 pounds per square inch but higher pressures are required for certain thrust and step bearings and in connection with high-grade automobile engines having the full force-feed system of lubrication. These engines are equipped with a pump that takes the oil drainage from a reservoir at the bottom of the crankcase. This oil is pumped at a pressure exceeding the bearing pressure, or from 30 to 60 pounds per square inch, to the main bearings. From the main bearings, the oil passes through a hollow crankshaft to the crankpins, then through hollow connecting-rods to the wrist-pins, and through hollow wrist-pins to the cylinder walls, from where it falls back to the crankcase sump. Highly developed oiling systems are also used on steam turbines, crosshead-type Diesel engines, and reduction gears. These systems are of the full force-feed pressure type, equipped with filters, coolers, and settling tanks. Several types of filters are in use; some of these remove the dirt by forcing the oil through a layer of hot water. Such a filter cannot be used for a saponifying oil. Others strain the oil through toweling or wicking, while still others use a centrifugal separator to clear the oil of dirt, etc.

Flooded Lubrication. — The difference between flooded lubrication and forced lubrication is that, in the former case, the oil is supplied to the bearing under a low pressure which insures that the journal is always flooded at the point where the oil is applied, but the lubricant is not forced between the surfaces rubbing against each other. In the forced-lubrication system, the oil is supplied at a pressure which is greater than the pressure between the rubbing surfaces at the point of application of the oil, and, hence, the oil is forced in between the surfaces. Of the less perfect means of lubrication, the ring or chain oiling method seems to give very satisfactory results.

Grease Lubrication. — Various classes of grease lubricants are used in bearings, especially if the speeds are low and the pressure high. Hand compression grease cups are extensively used for retaining the supply and

feeding it to the bearing as the bonnet or top is screwed down. Feed cups of the gravity type are adapted for lineshaft lubrication, cranes, etc. These cups contain a soft copper rod which bears lightly on the revolving shaft so that the rod vibration and the generation of some heat causes the grease to flow down the rod on to the bearing. The automatic compression cup is used for cross-heads, eccentrics, crankpins, slides, etc. The feeding pressure is supplied either by springs or compressed air.

LUMBER WATER CONTENT. The origin of lumber has a noticeable effect on its water content. Lumber or veneer (thin lumber produced usually by rotary cutting or flat slicing, sometimes by sawing), when produced from the log, contains a large proportion of water, ranging from 25 to 75 per cent of the total weight. One square foot (board measure, one inch thick) of gum lumber, weighing approximately five pounds when sawed, will be reduced to about three pounds when its water content of approximately one quart has been evaporated. Oak grown on a hillside may contain only a pint (approximately 1 lb.) and swamp gum may have from 2 to 4 pints of water per square foot, board measure. This water content of wood exists in two forms — free moisture and cell moisture. The former is readily evaporable in ordinary air drying, but the latter requires extensive air drying (several years) or artificial treatment in kilns. It is possible to use artificial means to remove the free moisture, but a simple air exposure is usually more economical.

LUMEN BRONZE. Lumen bronze is a bearing metal which combines in a marked degree the wearing qualities of babbitt with the strength and rigidity of phosphor-bronze. It is an alloy of zinc, copper, and aluminum, which, strictly speaking, therefore, is not a bronze at all, but a brass composition. It is from 20 to 25 per cent lighter in weight than ordinary bronze, is non-magnetic, is easily worked by machine tools, and is softer than machine steel, so that it will not score or cut the journal of the shaft. The weight per cubic inch is about 0.25 pound; the specific gravity, 6.93; the tensile strength, 33,000 pounds per square inch; the compressive strength, 80,000 pounds per square inch; the Brinell hardness, 119; the fusing point, 725 degrees F.; the shrinkage of sand castings, $\frac{7}{64}$ inch per foot, and the coefficient of expansion, 0.000015 per degree F.

LUMNITE. An aluminum cement having the trade name of "lumnite," consists essentially of 40 per cent alumina, 40 per cent lime, 15 per cent iron oxide, and 5 per cent silica, magnesia, etc. This material has two unique properties, one being that it reaches its full strength in 24 hours as compared with 28 days for portland cement, and the other its resistance to chemical attack. It has been found that it is unaffected by sea water or by sulphate-bearing ground waters.

MAAG GEARING. In the design of the Maag system of gearing, a 15-degree pressure angle is maintained for large gears, but for relatively small gears the angles and also the blank diameters or positions of the teeth relative to the pitch circles, are varied with the idea of obtaining the most satisfactory operation for gearing of a given ratio. This is a departure from standardization and the use of gears which are interchangeable at standard center distances. Those advocating this system, however, believe that what is lost in this respect is more than gained by so forming the teeth of a gear and pinion of given ratio as to obtain more rolling and less sliding action combined with stronger teeth without under-cutting, even when the gears are very small. When necessary or desirable to use gears having possibly not more than five or six teeth, a practical tooth form may be obtained by changing the pressure angle and the relation of the tooth to its pitch circle, to suit the conditions. It has long been the practice to obtain an improvement of tooth shape by the enlargement of small spur and bevel pinions but with the Maag system, the plan is to so modify the relations between addenda, dedenda, and pressure angle as to secure what is considered the best tooth form for each particular ratio.

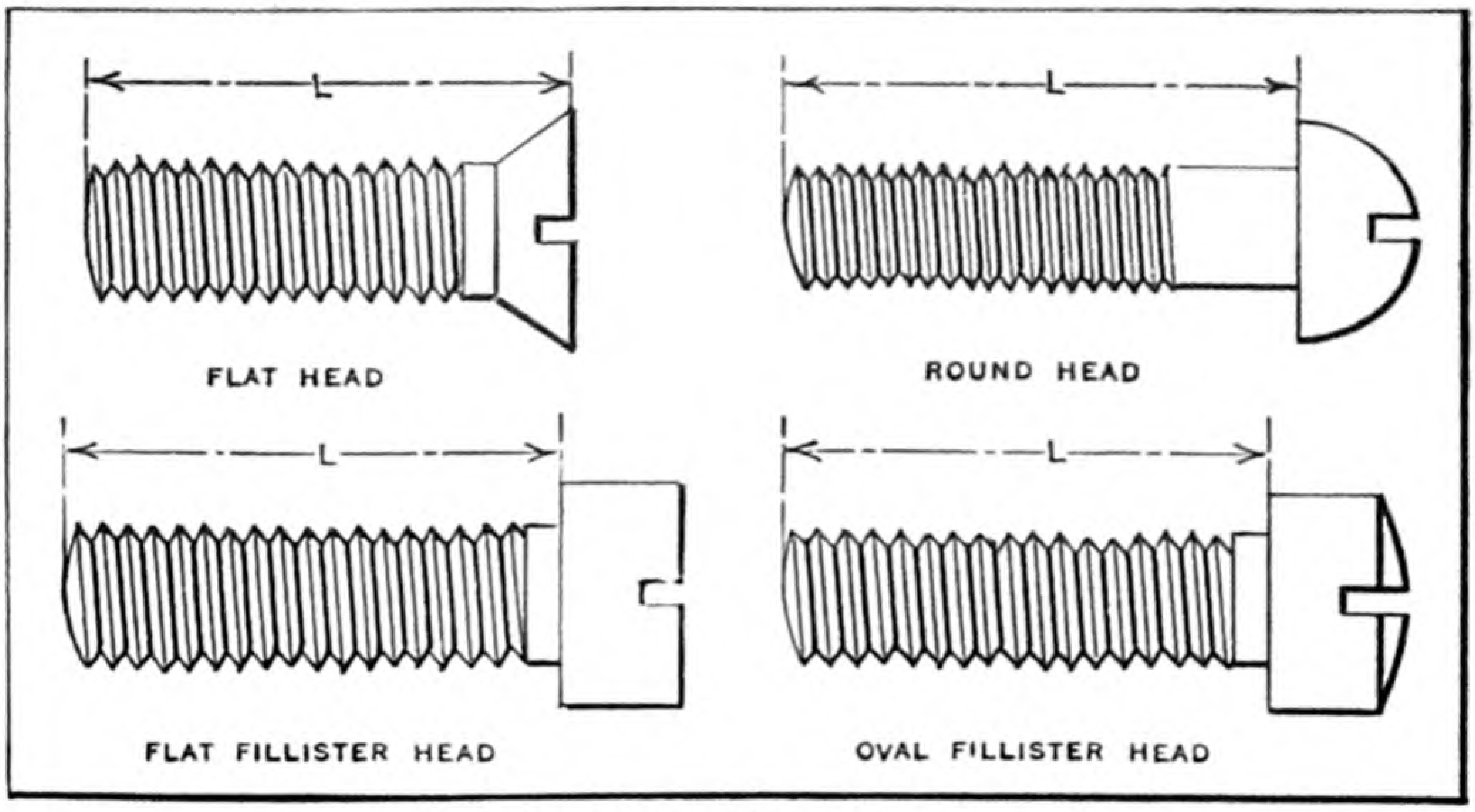
"MACHINE-HOUR" OVERHEAD DISTRIBUTION. See Overhead Expense Distribution.

MACHINE NUT TAPS. A machine nut tap (or machine tap, as it is also generally called) is used for nut tapping in tapping machines, the same as the tapper tap. The names of these two taps are often confused. From a manufacturing point of view, however, there is distinct difference between the two kinds of taps. The tapper tap is a very simple design, but for some classes of work the machine tap is more satisfactory. The machine tap is threaded and relieved in a different manner, and is adapted for use in tough material and for heavy duty.

MACHINE SCREWS. The term "machine screw" is applied to various forms of small screws, but is generally understood to mean a screw which enters a tapped hole in a machine part and one having a head that is slotted to receive a screw driver. Screws of this class, are designated by numbers instead of the actual sizes, (the numbers increasing with the diameter) excepting American Standard sizes $\frac{1}{4}$-inch and larger. See p. 666. The basic form of thread is the same as that of the United States Standard system.

The standard forms of machine screws in general use are shown in the illustration. These are classified as flat head, round head, flat fillister-head, and oval fillister-head screws. The letters L in this illustration indicate the dimension corresponding to the nominal length of the screw. Machine screws and cap-screws which have heads of the same shape, are not given

corresponding names by most screw manufacturers. For comparison of the different names which are applied to the same shapes see Cap-screw Names.



Typical Machine Screws

MACHINE SCREW STANDARDS. The first standard to be recognized by most machine screw manufacturers was the one adopted by the American Society of Mechanical Engineers in 1907. The A.S.M.E. standard was established to replace the private standards of screw manufacturers, which varied to a certain extent. The A.S.M.E. standard includes two series of pitches. The series for the finer pitches is known as " standard " and the series for the somewhat coarser pitches is designated as " special." The pitches in the A.S.M.E. standard were based largely on standards formerly adhered to by prominent screw manufacturers. While these standards varied more or less, pitches for certain sizes were in general use, and the A.S.M.E. " special " series includes practically all of these more common pitches; consequently, the adoption of the " special " series by the screw manufacturers involved comparatively few changes, and the result is that most machine screws on the market at present conform to the A.S.M.E. " special " series of pitches (with a few exceptions), rather than to the series designated as " standard."

American Standard. — The A.S.M.E. standard (including the " standard " and " special " series) has been superseded, in so far as official recognition of the society is concerned, by the National or American screw thread standard, which includes machine screw sizes, as well as larger screw threads, up to diameters of 3 inches. Many of the screw sizes and pitches of the new standard (within the usual range for machine screws) are the same as the

A.S.M.E. standard. As we are now dealing with machine screws, what follows will apply only to that part of the National or American standard that covers the ordinary range of machine screw sizes.

Machine Screw Sizes and Standard Pitches

Screw Number or Size	Outside Diameter of Screw Thread, Inch	Threads per Inch				
		National or American Standard		A.S.M.E. Standard		Other Pitches Used by Some Manufacturers
		Coarse Thread Series	Fine Thread Series	Standard	Special	
0	0.060	..	80	80	.....	.....
1	0.073	64	72	72	64	.....
2	0.086	56	64	64	56	48
3	0.099	48	56	56	48	.....
4	0.112	40	48	48	40–36	32
5	0.125	40	44	44	40–36	32
6	0.138	32	40	40	36–32	30
7	0.151	..	..	36	32–30	.....
8	0.164	32	36	36	32–30	.....
9	0.177	..	..	32	30–24	.....
10	0.190	24	32	30	32–24	.....
12	0.216	24	28	28	24	20
14	0.242	..	..	24	20	18
$\frac{1}{4}$	0.250	20	28	..	.....	.....
16	0.268	..	..	22	20	18–16
18	0.294	..	..	20	18	16
$\frac{5}{16}$	0.3125	18	24	..	.....	.....
20	0.320	..	..	20	18	16
22	0.346	..	..	18	16	.....
24	0.372	..	..	16	18	14
$\frac{3}{8}$	0.375	16	24	..	.....	.....
26	0.398	..	..	16	14	.....
28	0.424	..	..	14	16	.....
$\frac{7}{16}$	0.4375	14	20	..	.....	.....
30	0.450	..	..	14	16	.....
$\frac{1}{2}$	0.500	13	20	..	.....	.....

Machinery

According to this new standard, sizes from 0.060 inch up to $\frac{1}{4}$ inch are designated by numbers, following the universal practice for machine screws; the $\frac{1}{4}$-inch diameter and larger sizes are expressed by fractional dimensions.

The differences between this new standard and the A.S.M.E. standard are shown by the accompanying table which includes only the smaller diameters of the new standard or those within the ordinary range of machine screw sizes. As this table shows, the National or American " coarse thread " series is the same as the A.S.M.E. " special " series up to the ¼-inch size, except that the latter contains two pitches for all screws between numbers 4 and 10, inclusive, and, in addition, numbers 7 and 9 represent sizes not included in the newer standard. Since the A.S.M.E. " special " series has been the most prevalent machine screw standard up to the present time, naturally the " coarse thread " series of the new standard is the one that is being applied mostly in machine screw manufacture. In this " coarse thread " series, the use of two pitches for sizes from 4 to 10 was discontinued and the pitches selected are the ones most commonly used.

The National or American standard screws of ¼ inch size and larger differ entirely from the A.S.M.E. standard, the odd diameters of the latter having been superseded by common fractional dimensions, and a number of sizes considered unnecessary having been omitted. The new standard retains the U. S. form of thread, and the sizes of ¼ inch and larger in the " coarse thread " series conform to the U. S. standard, whereas the " fine thread " series from ¼ inch up to 1½ inches agrees with the S.A.E. standard.

MACHINE STEEL. Machine steel is a black stock of a better grade of steel than cold-rolled steel and requires machining. It contains from 0.25 to 0.45 per cent carbon It is the most commonly used steel, and is adapted for all machine parts that are not subject to strain or shock. For short shafts, studs, arbors, etc., it will give long service and withstand considerable strain if casehardened.

MACHINE TOOL. A machine tool is a machine-building tool; that is, a tool or machine for building machinery. Machine tools have also been defined as machines which, when taken as a group, will reproduce themselves. This definition has the disadvantage of being general rather than specific, and as a secondary definition the following has been suggested: " A machine tool is any metal-working tool the waste from which is in the form of chips." This is specific and can be easily applied to any particular machine. It is not necessary to define a metal " chip," but it may be advisable to recall that a grinding machine produces chips, even though small. This classification includes all metal-cutting machinery the action of which is a progressive cutting away of surplus stock — a gradual reduction in size until the finished dimensions are reached — but excludes sheet-metal working machinery and metal-forming and forging machines. A press, when used for piercing sheet metal, has very little in common with a lathe, a milling machine, or a planer. They are all metal-cutting machines, but here the

similarity ceases. The metal is not in the same form, and the cutting tools have nothing in common with other metal-cutting tools as to construction or cutting angles. When a press is used for forming, it has nothing in common with lathes, etc., other than the fact that they are all metal-*working* machines, as are also power hammers, bulldozers, swaging machines, etc.

The United States Treasury Department, in the collection of custom duties, defines machine tools as any machines operated by other than hand power, and which employ a tool for working on metal. This is a very broad definition and includes machines which, by some are not classified as machine tools, while they are so considered by others, such as shearing and punching machines, presses, and forging machinery. Another definition that is rather too long for convenient use, but which otherwise is quite satisfactory, is as follows: " A machine tool is any hand- or power-driven mechanism actuating cutters, tools, dies, or other forming or shaping implements, to perform any process or operation in making tools, machines, structures, or any part thereof, from metal, in distinction from one for producing a special or specific article." The fundamental types of machine tools, including only the machines that are always classified as such, are lathes, planers, shapers, slotters, milling machines, drilling and boring machines, and grinding machines. Nearly all other types can be classified as belonging to one of these groups. For information about different types of machine tools refer to name of type. See also Automatic Machine Tools; Hydraulic Transmissions; Single-purpose Machine Tools.

MACHINE TOOL HISTORY. The development of simple tools into more complex designs to replace manual labor is comparatively recent, and may generally be considered as having begun near the end of the eighteenth century. The history of civilization since that time has been so profoundly affected by the work of the engineer and the mechanic that the past and the present century may well be called the " age of machinery." The facilities for cutting metal in 1780 were little better than those of the middle ages. The mechanics or millwrights of that day worked almost wholly with the hammer, chisel, and file. Without doubt, the best mechanics during the eighteenth century were the French, and their work contained suggestions of a number of the modern machine tools; but their tendency was toward refined handicraft and ingenious novelties, and they showed little inclination toward commercial production on a large scale. The real development of the modern machine tool has taken place almost wholly in England and in the United States. The general machine tools, such as the lathe, planer, shaper, drill press, and steam hammer, and the small tools, such as taps and dies, were developed in England from about 1800 to 1850. In America, partially overlapping this period, but in the main in the latter part of the

nineteenth century, were developed the automatic lathe, the universal milling machine, drop-hammers, special machine tools of various kinds, and the interchangeable system of manufacture, the last involving the use of jigs, fixtures, and limit-gages.

MACHINE TOOL MOTORS. The load demand upon a motor driving a machine tool of the rotary type such as a lathe, boring mill, or drilling machine, is made up of machine friction plus the power required to remove the metal. The relative values of these two items vary. The load demand of a reciprocating tool such as a planer or shaper, involves the same items and, in addition, the power required to start, stop, and reverse the reciprocating parts. The load of a rotary machine may be quite constant, as in the case of a lathe making a continuous cut. If the cut is not continuous, the load may fluctuate considerably. The load of a reciprocating machine is inherently of a fluctuating nature, and the reversing peaks may be an important or determining factor.

The frictional load of a machine tool depends upon its design, and cannot be determined by formula. It may be best found by test. The power required to remove metal depends upon the character of the metal, rate of removal, average thickness of chip before distortion, and type and condition of tool. The following figures are widely used for lathes, shapers, boring mills, and planers:

Material	Horsepower Required to Remove 1 Cubic Inch per Minute
Brass	0.2 to 0.3
Cast iron	0.3 to 0.5
Wrought iron	0.6
Mild steel (0.30 to 0.40 carbon)	0.6
Hard steel (0.50 carbon)	1.00 to 1.25
Very hard tire steel	1.5

The power required for drilling is about double that given, due largely to friction between the drill and the side of the hole.

Heavy cuts requiring high torques are usually taken at relatively low speeds, while lighter cuts are taken at higher speeds. Thus the load tends toward a constant horsepower characteristic.

Motor Characteristics. — Machine tools are sufficiently varied in their requirements so that several types of motors find application in individual cases. A considerable portion of the total field requires a constant-speed drive with no unusual features. Here the direct-current, shunt motor or the alternating-current, squirrel-cage induction motor may be used with equal success. Either type will effect some gain over constant-speed belt drive from a line-shaft.

Many machine tools require adjustment of speeds over varied ranges, some as high as 30 to 1. Adjustable-speed direct-current motors are inherently best suited to such machine tools. Some machines, such as punches and shears, particularly when equipped with flywheels, require high starting and pull-out torque, together with drooping speed regulation. Here the compound-wound, direct-current motor or the high-slip induction motor is applicable.

Owing to the fact that alternating current is more commonly available, particularly in the smaller shops, the manufacturers of machine tools have adopted extensively the use of the gear-box for speed changes, thus adapting their tools for induction motor drive. For reasons of standardization, the same tools are then offered for use with constant-speed, direct-current motors, where the latter current is available. From the viewpoint of the machine tool builder, this standardization is desirable. In many cases, particularly for small machines, the practice is commendable. Where direct current is available, however, it will often benefit the user to employ adjustable-speed motors and eliminate the gear-box, or greatly reduce the number of change-gears required.

Adjustable-speed Direct-current Motors. — The adjustable-speed direct-current motor is excellently suited to the requirements of many machine tools. Owing to varying diameters, materials, and cuts, it is necessary to operate over a wide range of speeds. A selection of speeds can be had by the use of cone pulleys, while a greater number is available by the use of a gear-box. The adjustable-speed motor provides a finely graduated selection of speeds over a range up to 4 to 1. If a wider range is desired, a simple set of change-gears will suffice to extend the range.

The great advantage to be derived from the use of the adjustable-speed, direct-current motor lies in the fact that maximum permissible cutting speeds may be maintained and the speed may be readily manipulated. When speed changes must be made in sizable increments, it is necessary to use a speed lower than but approaching the desired rate. The margin represents a direct loss of production. Increased production has the double aspect of lower unit cost and less time required, lowering the overhead and facilitating good deliveries and quick repairs.

Use of Induction Motors. — It is not to be inferred that adjustable-speed, direct-current motors should be universally applied. When speed control features are unnecessary and a constant speed is satisfactory, the induction motor can be used to advantage. Records indicate that induction motors are somewhat more free from troubles and require less repairs than direct-current motors. It is perfectly possible to have an equipment of direct-current motors and control, if properly selected and applied and properly maintained, that will require a few repairs. An induction motor, improperly

applied or neglected, will stand up better than a direct-current motor under like conditions. It must also be considered that more is usually expected of the direct-current motor and control in the way of starting, stopping, reversing, and speed control, and the machine itself is thereby simplified.

In some cases, both alternating- and direct-current power supplies are available. In other cases, alternating current only or direct current only is available. Under the latter conditions, direct-current motors will be used exclusively. In a small shop where alternating current only is available, it is ordinarily best to use constant-speed, induction motors, foregoing the advantage of adjustable speed to avoid conversion. For larger shops, it may be advisable to install a converter or a motor-generator to supply direct current for all or a portion of the machines. The use of both alternating-current and direct-current motors in the same shop may or may not be advisable. When a number of large, constant-speed drives are required, alternating current should be used if available, even if a mixed installation results. If there are but a few constant-speed drives, direct-current motors may well be used for the sake of uniformity and to avoid two systems of current distribution. In some cases, direct-current motors have advantages in controllability even for constant-speed drives.

Load and Speed Ratings for Machine Tool Motors

Horsepower	3 to 1 Ratio	4 to 1 Ratio
	R.P.M.	R.P.M.
2	700–2100	500–2000
3	650–1950	500–2000
5	650–1950	450–1800
7½	600–1800	450–1800
10	600–1800	400–1600
15	550–1650	400–1600
20	500–1500	400–1600
25	500–1500	400–1600
35	500–1500	300–1200
50	400–1200	300–1200

Motor Ratings for Machine Tool Service. — Machine tool duty is not considered as continuous, but is more or less interrupted or varying. For this reason, adjustable-speed, direct-current motors are given a special intermittent rating known as the machine tool rating. This is the 60-minute rating on a 50-degree C. rise basis, open or semi-enclosed, and on a 55-degree C. rise basis, totally enclosed. The motor nameplate carries,

in addition, a continuous-duty 50-degree C. rise horsepower rating. The standard horsepower and speed ratings for adjustable-speed machine tool motors are given in the table on page 671.

MACHINE TOOL MOTORS, CONTROL. Inasmuch as controllability is one of the benefits of motor drive, the selection of the most advantageous control equipment is important. The principal functions of machine tool controllers are: (1) To start and stop the motor; (2) to reverse the direction of rotation; (3) to change the speed of the motor; (4) to provide a dynamic brake for stopping; (5) to provide a drift point; (6) to protect the motor and control; and (7) to protect the operator.

Manual Control. — For machine tools requiring simple starting and stopping, an enclosed faceplate starter is the cheapest installation. When the duty is infrequent, this may suffice. The drum controller is better adapted for manual control when the service is at all severe. Drum controllers offer a greater range in controllability, and are commonly arranged for reversing service. If desired, speed control may be had, both by armature and field resistance methods.

If there is any possibility that the starting resistance may be employed for obtaining speed control, either intentionally or inadvertently, series resistors should be designed for regulating duty. The use of "starting duty" resistors in connection with drum controllers for machine tools is a doubtful practice. Drum controllers for machine tools may be and frequently are equipped with a dynamic braking provision to afford a quick stop. On such controls a drift point is also provided in case it is desired to remove the driving power without braking. Drum controllers include no protective features. Either a separate protective panel or a circuit breaker is a necessary adjunct to provide overload and undervoltage protection.

Magnetic Control. — Magnetic control offers many attractive features for machine tool application. This type of control affords even greater flexibility of function than the drum controller. It includes protective features. Its location can be remote from the machine, which is often an advantageous arrangement. The control station comprises merely a few push-buttons or a compact and easily operated master controller. It requires a minimum of thought and attention on the part of the operator. Magnetic controls are particularly desirable where frequent starting, stopping, reversing, or manipulation is involved.

For the sake of uniformity, it will usually be found good practice to provide all direct-current motors, except perhaps the very smallest, with magnetic control. Push-button control stations may be used for the simpler controls, while master switches are preferable when greater manipulation is required. Simplicity and ruggedness are cardinal features. The panel should be totally enclosed for protection against dirt and tampering. The

operating master or push-buttons should, of course, be located at the machine and where most accessible to the operator. Convenience in the location of control stations is a small matter but an important one. It may be desirable to be able to control a machine from more than one point. Duplicate stations, pendent switches, or mechanical extension devices are sometimes used to this end.

Some control equipments have been simplified and reduced in size to make them more suitable for convenient mounting on the frame or incorporation in the pedestal or housing of machine tools. Making the control and motor an integral part of the machine has advantages of built-in wiring between the motor and control, compactness, testing as a unit by the machine tool manufacturer, and requiring a minimum amount of wiring upon installation.

When magnetic control is applied to adjustable-speed motors, it will generally be found more convenient to install a separate field rheostat at the machine. This rheostat should be enclosed and protected as well as possible. In some cases, on repetition work, it may be desirable to locate the field rheostat at the panel, where it may be set for predetermined speed operation and possibly locked at that point.

In selecting an adjustable-speed motor, the fact should be considered that the speed range is determined by the rheostat resistance. It is not always necessary to utilize the full range of the motor rating. For instance, a motor rated 400/1600 revolutions per minute may be operated at from 400 to say 1300 revolutions per minute if the resistance is properly specified for that range. Care should be taken to avoid excessive or unsafe speeds by using too large a speed range. If the rheostat has too much resistance, the excess portion should be shunted out.

When adjustable-speed motors are used in conjunction with magnetic controllers, some form of field strengthening relay will usually be desirable at starting. Particularly if dynamic braking is provided, it may be necessary to prevent too rapid field strengthening when reducing the speed or when stopping. In many cases, particularly where adjustable-speed motors are used with field resistors of necessarily fine wire, it is desirable to protect the motor and machine against overspeed in case of an " open " in the field circuit. This can be done by means of a field failure relay.

Alternating-current Drives. — For starting squirrel-cage induction motors, manual auto-starters are frequently employed. Automatic starters are gaining in popularity. These may be of the across-the-line, the auto-transformer, the primary resistance, or the primary impedance type. Drum reverse switches are available for use with such starters, if desired. The starting torque of most machine tools is low, except flywheel type drives, which require high-torque squirrel-cage or wound-rotor motors. Wound-rotor motors may be provided with either drum or magnetic control, the

latter being necessary for such drives as reversing planers and tapping machines. When there is a considerable number of large squirrel-cage motors installed in one shop, the use of one or two sets of transformers with partial voltage taps is suggested for consideration in conjunction with multi-voltage distribution and double-throw oil switches or contactors for starting.

The full possibilities of electric control are often overlooked. Mechanical means are sometimes employed at greater expense, when electrical control may accomplish the desired results in a better and cheaper manner. Control can be made to give quick start, stop and reverse, smooth acceleration and slow down, fine speed adjustment and overload protection both to motor and driven machine. It may make possible the elimination of clutches, slip gears, speed reductions and shifts, and other mechanisms.

MACKENZIE ALLOY. A white metal composition containing either 68 per cent of lead, 16 per cent of antimony, and 16 per cent of bismuth, or 70 per cent of lead, 17 per cent of antimony, and 13 per cent of tin, is known as Mackenzie alloy. This alloy is a good stereotype metal.

MAGAZINE FEEDING MECHANISMS. Machines which operate on large numbers of duplicate parts which are separate or in the form of individual pieces are often equipped with a mechanism for automatically transferring the parts from a magazine or other retaining device, to the tools that perform the necessary operations. The magazine used in conjunction with mechanisms of this kind is arranged for holding enough parts to supply the machine for a certain period, and it is equipped with a mechanical device for removing the parts separately from the magazine and placing them in the correct position wherever the operations are to be performed. The magazine may be in the form of a hopper, or the supply of parts to be operated upon by the machine may be held in some other way. The transfer of the parts from the hopper or main source of supply to the operating tools may be through a chute or passageway leading directly to the tools, or it may be necessary to convey the parts to the tools by an auxiliary transferring mechanism which acts in unison with the magazine feeding attachment. These automatic feeding mechanisms are usually designed especially for handling a certain product, although some types are capable of application to a limited range of work. See also Power Press Magazine Feeds.

MAGNALAMP. The name "magnalamp" has been given to an ordinary carbon or metallic filament lamp which is provided, at the point where the ordinary lamp screws into the socket, with an electromagnet, so that the lamp can be applied to iron or steel, or to any structure that is entirely or partly composed of iron and steel, the magnetism causing it to attach itself tightly enough to withstand considerable pull.

MAGNALIUM. Magnalium is a light-weight alloy composed of aluminum and a small percentage of magnesium. The composition varies,

but the alloy generally contains from 1.6 to 2 per cent of magnesium. It also contains small percentages of copper, nickel, tin, and lead, the last-mentioned metal probably being an impurity. The specific gravity of this alloy varies from 2.5 to 2.57. The tensile strength of magnalium sand castings containing 2 per cent of magnesium is 17,900 pounds per square inch, while with 10 per cent of magnesium the tensile strength is increased to 21,400 pounds per square inch. Wire drawn from one quality of the alloy has a tensile strength of 41,000 pounds and 10 per cent reduction of area, while it will stand 53,000 pounds, if the raw material has been forged before drawing. Soft rolled sheets have a tensile strength of 42,000 pounds and 15 per cent reduction of area; hard rolled sheets, a tensile strength of about 52,000 pounds and 3 per cent reduction of area. Magnalium containing less than a certain percentage of aluminum cannot be rolled, but can readily be drawn. The tensile strength of a drawn bar when tested was 60,000 pounds, and that of a tube, 74,000 pounds per square inch. Magnalium can be cast in a manner similar to that employed for aluminum.

MAGNESIUM ALLOYS. This is a series of light-weight alloys containing from 80 to 95.5 per cent of magnesium, the remainder being made up of other metals, principally aluminum.

MAGNESIUM CARBONATE. Magnesium carbonate, commonly known as magnesia, is an impurity often found in boiler feed water. It is soluble in pure water. It is held in solution, if sufficient carbonic acid gas is present, the same as calcium carbonate, and is precipitated if this gas is driven off.

MAGNESIUM CHLORIDE. This is a compound which, when present in boiler feed water, has a corrosive effect and which is one of the causes of "pitting" in boilers. The corrosive effect of magnesium and calcium chlorides come from the chlorine which is liberated by certain chemical changes. Magnesium chloride is very soluble in water, and evolves heat when in solution.

MAGNESIUM SULPHATE. Magnesium sulphate (sulphate of magnesia or Epsom salts) dissolves very slowly in cold water, but dissolves easily in warm water. It is a very common substance, and does not form scale, but, when present with calcium carbonate, a chemical reaction takes place which produces hydrate of magnesia and calcium sulphate, resulting in the formation of a very hard scale.

MAGNET. A magnet is a body which possesses the property of attracting pieces of iron and steel with a force in excess of the gravitational force and which, when freely suspended, takes up a definite position north and south. A magnetic substance is one which, when placed in the proximity of a magnet or a conductor carrying an electric current, will acquire the properties of a magnet. The most highly magnetic substances are iron and steel.

MAGNETIC ATTRACTION. The law governing the attractive or repulsive force of magnetism is the same as that which applies to gravity. When the distance between two magnetic poles is doubled, the intensity of the magnetic field is diminished to one-fourth; if tripled, the intensity of the field is reduced to one-ninth, etc. In other words, the attractive or repulsive force varies inversely as the square of the distance between the poles, it also varies proportionately as the product of the strength of the poles.

MAGNETIC CHUCKS. Magnetic chucks are devices by means of which objects of iron or steel may be held in position during machining operations, the holding power being the magnetism created by electromagnets in the chuck; hence, jaws, clamps, or bolts are not required. These chucks are made in rectangular, circular, and special forms and they are used on different types of machine tools such as surface grinders and planers.

MAGNETIC CLUTCHES. Magnetic clutches may be obtained having horsepower ratings varying from one to two horsepower up to several hundred horsepower. Such clutches are adapted particularly for high-speed drives, for heavy duty, and for use when there is difficulty in starting a heavy load with a motor. Magnetic clutches are also useful when machinery must be stopped quickly, a brake being used in such cases in combination with the clutch. One design of magnetic clutch has the field or driving member and the armature or driven member each carried by a flexible spring-steel plate so that when current passes through the field winding, the armature is attracted to it and friction surfaces come into engagement. The magnetizing winding of the field receives current through two collector rings and graphite brushes, and direct current is used. The clutch driving capacity depends upon the friction surfaces which are held together by the magnetic attraction.

MAGNETIC DEGREE. The 360th part of the angle subtended, at the axis of an electrical machine, by a pair of its field poles, is designated as a "magnetic degree." One mechanical degree is thus equal to as many magnetic degrees as there are pairs of poles in the machine.

MAGNETIC-MECHANICAL ANALYSIS. Research work done abroad and at the U. S. Bureau of Standards has shown that the magnetic properties of iron and steel afford a valuable index to the structural conditions existing in such materials, which is of particular importance for those materials the strength or cutting properties of which are the essential factors. Not only do the initial processes of manufacture affect the magnetic characteristics, but subsequent heat-treatment also. Therefore, the magnetic test offers means of examining materials, tools, etc., during and after manufacture, without injuring or marring them, with a view to predetermining their mechanical performance. It also presents a method of investigating the "exceptional tool" or product, looking toward its routine duplication.

The method of " magnetic-mechanical analysis " is based upon the fundamental fact that " there is one, and only one, set of mechanical characteristics corresponding to a given set of magnetic characteristics, and conversely there is one, and only one, set of magnetic characteristics corresponding to a given set of mechanical characteristics." Consequently, the magnetic properties of iron and steel give valuable information concerning structural conditions existing in the material. Apparatus for investigation of mechanical properties by determination of their correlated magnetic characteristics is known as a " permeameter." This instrument may be used for testing milling cutters, reamers, twist drills, files, etc., and also for testing such products as wire, wire rope, drill rod, etc. An advantage of the method is that the entire piece is tested instead of a sample, and the test is made without in any way damaging the product, so that this method is equally applicable for use on raw materials and finished work.

MAGNETISM. All magnetic substances may be considered as being made up of small permanent magnets, called *magnetons*, which are supposed to be of a nature similar to minute crystals. If these magnetons point equally in every direction, they neutralize each other, and the bar of a magnet, as a whole, will not be a magnet; but, if more magnetons are lined up in one direction than in another, the bar develops magnetic poles and becomes a magnet. If all the magnetons are lined up in the same direction, the bar is fully magnetized. Magnetism, the same as electricity, may be considered to have two components, a force and a flow, the force or pressure being known as the intensity, and the flow, or magnetic current, being known as the magnetic flux. The magnetic field is the space through which the force or influence of a magnet is exerted. If an iron bar is placed in a magnetic field, each of the little magnetons tries to turn around like a compass, and, when turned, its magnetic field is in a direction to increase the total flow of flux. The stronger the field intensity, the more nearly will all the magnetons be turned into line, and the stronger a magnet the iron bar will become. A magnetic needle, or compass needle, is a magnetized piece of iron or steel which, being free to turn, always tends to point north and south, owing to the earth's own magnetic field. See also Diamagnetism.

MAGNETITE. Magnetite is the purest form of iron ore found in nature, and contains the largest percentage of iron obtainable in any ore. It is also known as " magnetic oxide of iron," or " black oxide of iron." Magnetite is strongly attracted by a magnet; hence its name. Magnetite sometimes possesses magnetic polarity, thus forming a natural magnet. The mineral is, in that case, known as " lodestone."

Iron is present in magnetite ores as a magnetic oxide, Fe_3O_4, which, when pure, contains 72.4 per cent of iron. Many of the commercial magnetite ores contain, as impurities, sulphur, phosphorus, and titanium, and some-

times the ore is mixed with an excess of rock, making the actual percentage of iron for a given weight comparatively small. Magnetite ore, when pure, is almost black, but the commercial ore varies in color from black to blue black, steel gray, or slightly green, having a hardness of from 5 to 6.5 on the Mohs hardness scale. See Iron in Iron Ore; also Hematite.

MAGNETO. A magneto or magneto-generator may be defined as a small and compact form of electric-current generator or dynamo, used for generating the small currents required for ignition purposes in internal combustion engines, for bell signals in telephone systems, etc.

MAGNET-OPERATED CONTROLLER. This is a power-operated electric motor controlling device, the simplest form of which is non-automatic and consists of a master controller, a contactor panel, and a resistance. The latter is cut in or out of circuit in steps by the magnet-operated contactors which short-circuit the resistance sections and, therefore, must carry the full current. The operator has perfect control of the motor, the same as with an ordinary hand-operated drum controller. The magnet-operated type is probably the most durable and flexible of all types of controllers. It can easily be made automatic, can be placed near the motor, and is independent of the location of the operator.

MAGNETS, LIFTING. Lifting magnets are used in connection with power-operated cranes and hoists, for lifting magnetic material, especially where such material must be handled in bulk. They are especially useful in and around foundries, steel mills, etc., for lifting such materials as pig iron, metal plates, billets, scrap iron, steel castings, rails, "skull crackers," and, in fact, practically anything except non-magnetic metals, such as brass and copper. The magnet is energized by a direct-current and it greatly facilitates handling material of the classes mentioned, because the parts to be lifted are gripped or released by the magnet instantly and quite a number of pieces can be lifted at one time, especially in the case of small billets, plates, etc. *Pig magnets* are designed to handle material of irregular shape that is piled indiscriminately. *Plate magnets* are especially adapted for lifting straight shapes from orderly piles. *Bi-polar magnets* are designed for handling both of the classes of materials mentioned in the foregoing. There are also magnets of special form which are designed particularly for handling a certain class of material. All lifting magnets require direct current. Where direct current is not available, it may be obtained by installing a motor-generator or engine-generator set.

MAGNET STEEL. Alloy steel is used for making permanent magnets. The composition of the steel depends to a large extent upon the class of service for which the magnets are to be used. Telephone magnets, for instance, are made from 0.50 to 0.60 per cent carbon steel, containing a fairly

high percentage of manganese. When a stronger magnet is required, as for magnetos, a 0.50 to 0.60 per cent carbon steel, with from 3 to 7 per cent of tungsten, is used. Steel containing $5\frac{1}{2}$ per cent of tungsten makes excellent permanent magnets. The grain of the steel should be such that, when heated above the decalescence point and quenched, it will show a fine-grained fracture.

MAGNOLIA METAL. A bearing metal composed of lead, tin, and antimony in somewhat varying proportions, but generally consisting of from 78 to 80 per cent of lead, from 15 to 16 per cent of antimony, and from 4.75 to 6 per cent of tin, is known as *magnolia metal*. In some samples, 0.25 per cent of bismuth and a trace of copper is present.

MAJOR DIAMETER. The largest diameter of the thread on a screw or nut is the "major diameter." This term has been used to replace the term "outside diameter" as applied to the thread of a screw and also the term "full diameter" as applied to the thread of a nut. See also Minor Diameter.

MALLEABLE CASTINGS. Malleable-iron castings are produced by subjecting ordinary white iron castings to a special heat-treatment, in order to make the castings tougher and to some extent malleable. Hard, brittle, white iron castings that have been cast in the usual manner are first cleaned to remove any sand which may adhere to them, and then are packed in cast-iron or malleable-iron boxes or pots, with powdered hematite ore or iron scale. It is customary to arrange these pots three high in an annealing furnace or oven. In sets of three high the cold oven is filled to capacity, the doors are closed and sealed with fire-clay, and the fire is started. The purpose of the scale is to keep the fire from direct contact with the castings. The temperature is raised to between 1400 and 1700 degrees F. and is maintained there for forty-eight hours or longer; then the fire is allowed to die out and the oven cools slowly. As it ordinarily takes two days to obtain the required temperature, the whole process may require eight days from the time the fires are started until the castings are removed. It is essential that the oven be cooled very slowly from its high temperature, as this is a determining factor in the quality of the product.

Physical Properties. — Malleable iron possesses physical properties closely resembling those of wrought iron, and as it is primarily a cast metal, odd shapes, housings, etc., may be made which possess, to a marked degree, the properties of forged metal. Malleable iron is much stronger than cast iron, but weaker than steel castings, and can be bent and worked to some extent. Malleable iron can be hardened, and when so treated is especially adapted to the hardware class of castings. Malleable castings have a tensile strength commonly varying from 35,000 to 55,000 pounds per square inch with from 3 to 8 per cent elongation in two inches. Some castings have shown a tensile strength of from 60,000 to 63,000 pounds per square inch, and even stronger castings have been produced. Castings made of malleable iron

may be subjected to repeated shocks for long periods without crystallization; they will withstand considerable distortion without breaking, and malleable iron has greater rust-resisting properties than any of the other ferrous metals. Therefore, malleable castings are extensively used on railway equipment, agricultural implements, and machinery and various other classes of work subjected to corrosion and shocks. Malleable iron is less susceptible to fatigue failure than steel castings.

Malleable Iron Brittleness. — Numerous tests on samples of commercial malleable iron, mostly impact tests on specimens heat-treated at relatively low temperatures, show that the embrittlement of malleable iron sometimes noted in hot-dip galvanizing is due chiefly to the incidental heat-treatment. Quenching malleable iron from temperatures between 400 and 500 degrees C. (750 and 930 degrees F.) makes it brittle to a greater or lesser degree, depending on the iron. The rate of heating and the time the metal is held at this temperature exert but little influence. Ageing after treatment has no apparent effect. On the other hand, substituting slower rates of cooling for the quenching treatment produces a metal of higher impact resistance. Heating to 650 degrees C. (1200 degrees F.) for a few minutes, followed by quenching (in water at room temperature), eliminates the embrittlement, even if the metal is subsequently galvanized.

MALLEABLE COPPER. Malleable copper, also known as virgin copper and native copper, is a metallic copper found in nature practically pure, having all the properties of refined metal. It is mined extensively in the Lake Superior district in the United States and in Bolivia.

MALLEABLE PIG IRON. This is an American trade name for the pig iron suitable for converting into malleable castings through the process of melting, treating when molten, casting in a brittle state, and then making malleable without remelting.

MALLEABLIZING. Malleablizing, according to the S.A.E. definition, is a kind of annealing operation with slow cooling, resulting in the combined carbon in white cast iron being transformed to temper carbon; in some cases the carbon is entirely removed from the cast iron. Temper carbon is free carbon in the form of rounded nodules made up of an aggregate of minute crystals.

MALTHA. Maltha is a material obtained from Californian petroleum as a residue when the more volatile ingredients have been distilled off. It is used as a protective covering for sheet-steel riveted pipe, the maltha is thinned with mineral oils, heated, and the pipe dipped in it, the coating being allowed to dry in the air.

MANCHESTER PITCH. The term "Manchester pitch" formerly was used to designate a pitch system for gearing, and it was originated by John

George Bodmer in his plant at Manchester, England. Originally the pitch was obtained by dividing the pitch diameter by the number of teeth, thus obtaining a value similar to the module or metric pitch. The present diametral pitch obtained by dividing the number cf teeth by the pitch diameter, is equivalent to the reciprocal of the old Manchester pitch system. See Diametral Pitch.

MANDREL. See Arbor and Mandrel.

MANGANESE. Manganese is one of the most important of the minor metals. The ores are obtained from many parts of the world, including the United States, Brazil, France, Germany, and India. Manganese is used extensively in the iron industries in the manufacture of iron-manganese alloys, such as spiegeleisen, ferro-manganese, silver spiegel, and silico-manganese. Spiegeleisen and ferro-manganese are used largely in the manufacture of steel, as reducing agents and recarburizers. A considerable quantity of high-grade manganese ore is also used as a depolarizer in the manufacture of dry-cell electric batteries. Manganese steels have many important qualities not found in other steels. Manganese-bronze is produced by alloying manganese with copper, while so-called " silver-bronze " is obtained by alloying manganese with aluminum, zinc, and copper. Oxides of manganese are used in glass manufacture, and as dryers of varnishes and paints. Manganese is also used as a coloring material for staining glass, tiles, and bricks, as well as in calico printing and dyeing. The specific gravity of manganese is 7.42, making the weight per cubic inch, 0.268 pound. The specific heat at 32 degrees F. is 0.122; the melting point of manganese is 1225 degrees C. (2237 degrees F.). Its electrical conductivity is 15.75, that of silver being taken as 100. Manganese is a metal having a close resemblance to iron in many respects.

MANGANESE-BRONZE. There are a number of different manganese-bronzes which give satisfactory results. They generally contain from 56 to 60 per cent of copper, from 37 to 42 per cent of zinc, with small percentages of iron, tin, and manganese. The manganese content is not more than 0.3 per cent, and sometimes it is as small as 0.01 per cent. Nevertheless, it has a considerable influence upon the character of the alloy. Tests made indicate that the ultimate tensile strength of castings made from manganese-bronze of the composition mentioned is about 60,000 pounds per square inch, with an elastic limit of 30,000 pounds per square inch. Rolled manganese-bronze has a tensile strength up to 100,000 pounds per square inch, with an elastic limit of about 80,000 pounds per square inch. The elongation in rolled samples varies from 12 to 15 per cent, and in sand castings, from 8 to 10 per cent. The compressive strength of cast manganese-bronze varies from 125,000 to 135,000 pounds per square inch. Wrought manganese-bronze differs chiefly from the casting grade in being free from aluminum.

The addition of aluminum enables the alloy to be cast satisfactorily in sand molds. In order to secure ductility as well as high tensile strength, extreme purity of the materials used is absolutely essential. Manganese-bronze is stronger and tougher than phosphor-bronze, and has a high corrosion resistance. It is adapted for use in parts such as screw propellers, large gears, bearings, brake-shoes, etc. This material is preferable to aluminum bronze, as it is more easily handled in the foundry and produces better castings.

MANGANESE SILVER-BRONZE. A so-called "manganese silver-bronze" alloy, which can be rolled into sheets and rods and drawn into wire, is composed of 18 per cent of manganese, 1.2 per cent of aluminum, 13 per cent of zinc, 67.3 per cent of copper, and 0.5 per cent of silicon. This alloy has a tensile strength of about 57,000 pounds per square inch with 20 per cent elongation. It can be drawn into wires as small as 0.008 inch in diameter. This alloy is useful as a resistance wire in electrical devices, because its conductivity for the electrical current is only $\frac{1}{40}$ of that of pure copper; in fact, it has a much lower conductivity than that of German silver.

MANGANESE STEEL. Manganese steel was first successfully produced by the Hadfields in England, about thirty years ago, and was known as "Hadfield steel." It was first made in the United States by the Taylor Iron & Steel Co., of High Bridge, N. J. In making manganese steel, the composition is practically standard. The usual analyses of manganese steel lie between the following limits: carbon, 1.0 to 1.3 per cent; silicon, 0.3 to 0.8 per cent; manganese, 11.0 to 14.0 per cent; phosphorus, 0.05 to 0.08 per cent. Manganese steel is a hard self-hardening steel. It cannot be softened by heating followed by slow cooling, and, for a metal, is a poor conductor of electricity. Manganese steel has a high coefficient of expansion, small patterns being made with a shrinkage of $\frac{5}{16}$ inch to the foot, which sometimes is not quite enough. A shrinkage of $\frac{5}{16}$ inch to the foot gives a mean coefficient of expansion of about 0.000024 per degree C.

Perhaps the most remarkable property of manganese steel is its almost total lack of magnetic permeability and susceptibility. This metal, containing 85 per cent of iron in a metallic form, is so slightly attracted by a magnet that the pull cannot be felt by the hand, whereas magnetic oxide of iron, containing about 70 per cent of iron in a non-metallic form, is strongly attracted. The average commercial steel has a tensile strength of from 82,000 to 90,000 pounds per square inch, an elastic limit of from 45,000 to 60,000 pounds, and an elongation of about 30 per cent. Other approximate values are, compression, 163,000 pounds per square inch; shear, 80,000 pounds per square inch; melting point, 2450 degrees F.; weight, 0.284 pound per cubic inch (490 pounds per cubic foot), specific gravity, 7.88.

Manganese steel is used mostly for castings subjected to heavy strains,

shocks, and excessive wear, such as the wearing parts of steam shovels, ore and rock crushers, mining machinery, etc. It is also used to a considerable extent for safes. When rolled and forged, it is used for rails, frogs, and crossings.

MANGANIN. Manganin is an alloy containing manganese, copper, and nickel, which is used for electrical purposes; it possesses the peculiar property of not altering its electrical resistance with a change in temperature. This alloy, therefore, is used for wires in the construction of resistance boxes, electrical instruments, and standards. The composition which has proved most suitable for ordinary purposes consists of 85 per cent of copper, 12 per cent of manganese, and 3 per cent of nickel.

MANHÈS PROCESS. The Manhès process is a method of refining copper, which is similar to the Bessemer process for making steel. In the "bessermerizing of matte" by the *Manhès* or *converter* process, a blast is forced through the molten matte. In about 25 minutes this blast oxidizes all but a small quantity of iron and some sulphur, and has raised the product to white metal. The slag is poured and the blast again turned on for 30 or 40 minutes, when the sulphur is rapidly oxidized and the charge is reduced to metal containing 99 per cent of copper. Little or no slag results from the second blow; that from the first blow contains from one to two per cent of copper and is put into the reverberatory or blast furnace.

MANHOLE DIMENSIONS. In a steam boiler, a manhole is an opening large enough to permit a man to enter the boiler for inspection or repairs. Elliptical manhole openings must not be less than 11 by 15 or 10 by 16 inches in size. Circular manhole openings must not be less than 15 inches in diameter.

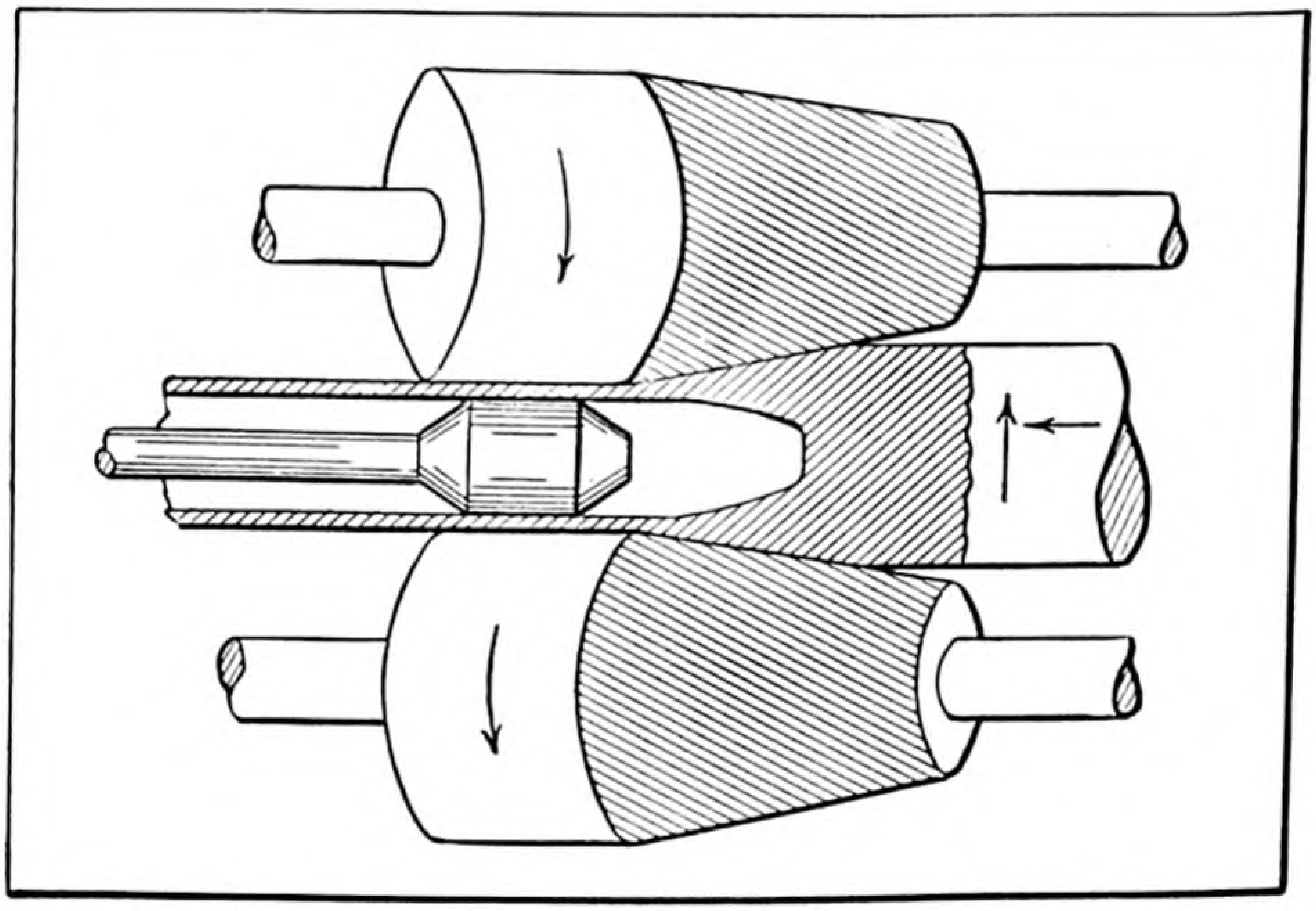
"MAN-HOUR" OVERHEAD DISTRIBUTION. See Overhead Expense Distribution.

MANIFOLD. (1) A fitting with numerous branches used to convey fluids between a large pipe and several smaller pipes. (2) A header for a coil.

MANILA ROPE STRENGTH. Manila rope is made from fiber or hemp obtained from a plant that is a native of the Philippines. Its strength varies considerably, not only with the quality of the fiber and the method by which the rope has been made, but also with the weather conditions under which it is used and the size and mounting of the sheaves over which it is run. Deterioration and wear is generally due to defective sheaves, excessive load, and exposure to outdoor atmospheric conditions. Manila rope in fairly good condition, $\frac{1}{2}$ inch in diameter, should safely support 250 pounds; $\frac{3}{4}$ inch in diameter, 750 pounds; 1 inch in diameter, 1500 pounds; $1\frac{1}{4}$ inches in

diameter, 2000 pounds; $1\frac{1}{2}$ inches in diameter, 2500 pounds; $1\frac{3}{4}$ inches in diameter, 4000 pounds; 2 inches in diameter, 5000 pounds; $2\frac{1}{4}$ inches in diameter, 7000 pounds; and $2\frac{1}{2}$ inches in diameter, 9000 pounds. When the load is supported by two or four parts of the rope, it is advisable not to multiply the load by two or four directly, but to make the load on several parts of rope slightly less than the theoretical safe load would be, figured from the safe load on a single rope, especially for large ropes. For example, when the safe load for a 2-inch rope is 5000 pounds, the safe load on two parts of rope may be 9000 pounds, and the safe load on four parts, 16,000 pounds.

MANNESMANN PROCESS. The piercing process used in the production of seamless tubes, commonly called the "Mannesmann process," is based upon the fact that the cross-rolling of a heated round bar of steel



Mannesmann Process of Making Seamless Tubes

produces a rupturing of the material along its center line, and a tendency to form a hole along its longitudinal axis. The diagram illustrates the principle of the Mannesmann piercing process. A round solid billet is passed between two rolls the axes of which are at an angle, as the illustration indicates. These rolls impart to the billet a high rotative speed and a slow advancing movement, forcing the billet over a pointed mandrel and thus increasing its length and changing it from the solid to the tubular form. The forward motion of the billet is caused by the inclination of the axes of the conical rolls relative to each other. A satisfactory explanation for the remarkable results obtained by this method is difficult to give. It seems that the

material, instead of flowing in a longitudinal direction, as in ordinary rolling, has a tendency to flow outward toward the circumference, owing to the rotary motion, and a distinct displacement of the fiber takes place. This method of piercing billets can be applied in a number of ways.

MANNHEIM GOLD. Mannheim gold is the name of an alloy containing according to one authority, 89.44 per cent of copper and 9.14 per cent of zinc, the remainder being impurities; another authority gives the composition as 75 per cent of copper and 25 per cent of zinc, or 80 per cent of copper and 20 per cent of zinc.

MANOGRAPH. The manograph is the name of an instrument used for indicating engines of very high speed. It consists principally of a small mirror moved or tilted upward and downward by a diaphragm actuated by the pressure variations in the cylinder. The mirror is also rocked from side to side by a mechanism geared to the engine, in order to reproduce the reciprocating motion of the engine piston on a smaller scale. The principle of action of the device is based upon the fact that a beam of light is reflected by the mirror on a ground-glass screen, and this beam, by the movement of the mirror, traverses a path corresponding to that of the pencil point of an ordinary indicator. The diagram is traced by the beam of light on the ground-glass screen, and varies with the varying conditions in the cylinder. A photographic dry plate in a plate-holder may be substituted for the ground-glass screen, and the diagram may thus be photographed. The exposure varies from one-half to three seconds. The instrument is especially used on gas engines, where the speed is too high for the ordinary type of indicator. See also Indicator, Engine.

MANOMETER. The manometer is an instrument for measuring the pressures exerted by gases or vapors; hence, the manometer is simply a pressure gage, although the term " pressure gage " is generally restricted to that type of manometer which is used in connection with steam boilers, air tanks, etc. The principle of the simplest form of manometer is based upon that law of hydrostatics according to which a liquid contained in a U-tube will show the surfaces at the same height in both vertical legs, if the pressures on the surfaces of the liquid in both are equal; but, if the pressure in one leg is greater than that in the other, the surfaces will be at different heights, the difference being proportional to the difference in pressure, and inversely proportional to the specific gravity of the liquid.

" MAN-RATE " OVERHEAD DISTRIBUTION. See Overhead Expense Distribution.

" MANUFACTURERS STANDARD " NUTS. See Nut Standardization.

MARBLE. Any limestone which is sufficiently compact to admit of being polished is known as "marble." Pure marble is white, but the presence of iron oxides or other impurities changes the color. Marble is of importance in electrical engineering, because of its insulating qualities, and is the material principally used for switchboard work, in which case it should contain no metallic veins, as these reduce its insulating qualities. The dielectric strength of marble is estimated at 6500 volts per millimeter (0.0394 inch). There is some difficulty in drilling or otherwise shaping marble. In drilling marble, the operation is greatly facilitated by grinding or filing a narrow slot in the point of the drill. This slot should be about $\frac{1}{8}$ to $\frac{1}{4}$ deep, according to the size of the drill, and should form an angle of a little less than 90 degrees with the cutting edges. Marble is a difficult material to turn. When turning is necessary, it should be cut with a tool such as is used for brass, but at a speed suitable for cast iron. It must be handled very carefully in order to prevent flaws in the surface.

MARINE GLUE. Marine glue, proof against the action of salt water, consists of 1 part of crude rubber, 2 parts of shellac, and 3 parts of pitch. The rubber is first dissolved in carbon disulphide or turpentine, and is then mixed with the heated combination of the two other ingredients.

MARIOTTE'S LAW. See Boyle's or Mariotte's Law.

MARKING MACHINES. Marking machines are used for imprinting trade marks, firm names, etc., on either flat or round surfaces of metal parts or products such as cutlery, files, fire-arms, drills, taps, reamers, etc. There are various designs of marking machines, some of which are operated by hand and others by power. One general type is provided with either a round steel stamp for flat work, or a flat stamp for round work, and means of traversing either the die or work while both are held in contact with sufficient pressure to transfer the lettering or design from the steel stamp to the parts being marked. The necessary traversing movement on small machines may be obtained by a crank or a hand lever, and on the larger machines by power derived either from a belt or motor drive. One type of power-marking machine is operated by placing a blank in position and starting the machine by foot treadle control; a cam then releases a weighted arm, thereby raising the work-table and bringing the work into contact with the die which traverses across the work. When the stroke is completed the table drops, the work is released, the die returns to the first position, and the machine stops. During the return stroke, the imprinted blank can be removed and a new one inserted. Another marking machine especially intended for such parts as bushings, tool handle ferrules, light sockets, spark plug parts, etc., has a horizontal revolving dial which carries the work across

the face of the marking die. If thin tubular pieces require internal support they are placed on mandrels. Parts can be marked very rapidly with a machine of this type.

MARTENSITE. Martensite is one of the molecular states of steel, into which the metal changes when heated to the hardening temperature and quenched; martensite consists mostly of iron with 2 per cent or less of carbon; it forms the chief constituent of hardened steel. It is hard, brittle, and non-magnetic. When its composition corresponds with that of pearlite, and it contains 0.9 per cent of carbon, it is known as *hardenite*. See also Steel Under the Microscope.

MASS AND WEIGHT. The mass of a given body is a constant value by means of which the *quantity* of matter the body contains may be compared with that of another body. Mass is a ratio obtained by dividing the weight of the body by the acceleration due to gravity. According to the law of gravitation the attractive force by which one body tends to draw another body towards it, is directly proportional to its mass and inversely proportional to the square of the distance between the centers of the bodies. This attractive force is greatest at the earth's surface; above the surface it decreases as the *square* of the distance, and below the surface it decreases as the distance to the center decreases. With these fundamental laws in mind the meaning of weight and the distinction between it and mass will be more apparent.

If the weight of a body is determined by scales of the beam or lever-balance type, a measure of the quantity of matter is obtained because the body balances a standard weight unit and both body and weight unit are equally affected by gravity changes which would result either from a change of altitude or latitude; hence weight determined in this way is constant regardless of locality. When a scale of the spring type is used, weight becomes a measure of the force of gravity and variations will occur, assuming that changes of altitude or latitude are sufficient to cause observable changes in the scale reading; hence the weight reading obtained with a spring type of scale might not be a true indication of the amount of matter, because with such a scale the force of gravity acts upon the body being weighed but does not appreciably affect the spring resistance. If the weight obtained with the spring type of scale is divided by the acceleration due to gravity for a given locality, the ratio obtained, which represents mass, will remain constant. To illustrate this point by using an extreme example, if the force of gravity is 32.16 (value commonly used in engineering) and the weight is 100 pounds, then mass equals $100 \div 32.16 = 3.11$. On the surface of the sun, where the force of gravity is twenty-eight times greater than on the earth, the same body would weigh 2800 pounds, but its mass would equal

$\frac{28 \times 100}{28 \times 32.16} = 3.11$. In this instance, there would be an extreme variation in the apparent weight in pounds (assuming that the spring type of scale were used) but the ratio representing mass is the same in each case. The quantity of matter represented by a body weighing 100 pounds on the earth, would not be altered in any way by a change of locality; hence, it is evident that the value representing mass is an indication of the quantity of matter that a body contains and this is also true of the weight as determined by a scale of the beam-balancing type. Mass is used in many calculations, such as those involving the motion of bodies, when "weight" means the attraction due to the force of gravity, which is the common meaning in theoretical mechanics. Sometimes mass is expressed in pounds, but since it does not mean an equivalent number of standard weight units, but is a ratio between weight and acceleration due to gravity, the use of pounds in connection with mass is confusing, if not misleading.

MASTER GAGES. Master gages are used only for verifying inspection gages, or for checking the product in case a disagreement arises between the manufacturer and the purchaser. Under the heading "master gages" are included various gages known as "checks," "masters," and "reference gages." Master gages should, if possible, be of the same design and construction as the inspection gages, but should have practically no allowance for wear. In some cases, checks or masters are made which are complements or the reverse of the inspection and working gages, as, for example, thread ring gages which are used for plug thread gages. All snap gages gaging below $\frac{1}{4}$ inch, and those so designed that they cannot be checked by ordinary measurements, should be provided with checks that are the reverse of the inspection gage itself. Master gages are of double importance to the manufacturer who has part of his product made outside of his plant, because occasions will arise when his own inspectors will reject work that the outside manufacturer claims to be correct. One set of masters should be kept at the outside manufacturer's plant and one at the home plant.

MASTER-PLATE LOCATING METHOD. When it is necessary to machine two or more plates so that they are duplicates as to the location of holes, circular recesses, etc., what is known as a "master plate" is often used for locating the work on the lathe faceplate. This master plate contains holes which correspond to those required in the work, and which accurately fit a central plug in the lathe spindle, so that, by engaging first one hole and then another with the plug, the work, which is attached to the master plate, is accurately positioned for the various drilling, boring or turning operations.

MATCHING. In the making of leather belting, matching is the process of fitting the pieces of leather cut from the right side of the hide with pieces

cut from the left side, because all strips which are not back-bone center pieces will stretch in a curve if subjected to sufficient strain, and hence require to be equalized by fitting in the manner outlined.

MATCH-PLATE PATTERNS. To expedite the molding, small patterns are often mounted on plates with the cope side of the pattern on one side of the plate and the drag on the other. Thus there is a series of patterns on one side of the match plate corresponding to half sections of the pieces to be cast. A second series of patterns, corresponding to the other half sections of the pieces is located on the other side of the match plate. The match plate is provided with eye-holes at each end to receive the guide pins on the flask.

In using a double-faced match plate for molding, the method of procedure is to put the match plate between the two halves of the flask. Sand is then rammed into the drag side of the flask, after which bottom boards are placed over the sand to prevent it from shifting when the mold is turned over. Sand is next rammed into the cope side of the flask. A cope board provided with a cup or button at the point of sprue is then placed on the sand, and the cope and drag are squeezed together. The cope is next lifted off the match plate after which the match plate is lifted off the drag. After the necessary hand work has been done in finishing the two halves of the mold, the cope side is placed on the drag, and the mold is ready to have the molten metal poured into it.

For many classes of work there is no better form of pattern than the double-faced match plate. A pattern of this type has all the advantages possessed by the so-called " gate of patterns " in that it allows a number of castings to be poured simultaneously, and in addition it provides a simpler means of making the molds. Double-faced match plates can be used either where the sand is rammed in the flask by hand, where a manually operated squeezer is employed, or where a power-driven jolt squeezer is used in the foundry. This type of pattern will usually be found to give the maximum results obtainable with any of these methods.

MATHEMATICAL SYMBOLS. The symbols used in formulas, as well as in algebra in general, are mainly the letters in the alphabet. Letters from the Greek alphabet are frequently used to designate angles, and the Greek letter π (pi) is always used to indicate the ratio between the circumference and the diameter of a circle; π, therefore, is always, in mathematical expressions, equal to 3.1416. The Greek letters most generally used, besides π, are α (alpha), β (beta), γ (gamma), δ (delta), θ (theta), μ (mu), ϕ (phi), and ω (omega). In general, any letter may be used as a symbol for any quantity. Ordinarily, however, the letters at the beginning of the alphabet are used as symbols for *known* quantities, and letters at the end of the alpha-

bet as symbols for *unknown* quantities; thus, in general, a, b, c, etc., would be known, and x, y, z, t, u, etc., unknown quantities. There are, however, a few symbols that are almost universally used to designate, at all times, certain fixed quantities. The most common of these follow: n, any number in general (thus a^n = nth power of a); d, differential (in calculus); e, base of hyperbolic logarithms (2.71828); g, acceleration due to gravity (32.16 feet per second); i, imaginary quantity ($\sqrt{-1}$); t, time; v, velocity; Δ (delta), difference; δ (delta), differential; μ (mu), coefficient of friction; Σ (sigma), sign of summation; ω (omega), angles measured in radians. There are also a number of expressions in the form of symbols generally used in mathematics, as follows: $a^2 = a$ squared (2d power of a); $a^3 = a$ cubed (3d power of a); a^4 = 4th power of a; $\sin^{-1} a$ = arc, the sine of which is a; arc $\sin a$ = arc, the sine of which is a; $(\sin a)^{-1}$ = reciprocal of $\sin a = 1 \div \sin a$.

MATHESON JOINT. The pipe joint known as the "Matheson joint," used for wrought-iron pipe, is made by enlarging one end of the pipe to form a suitable recess for lead, similar to the bell-end of a cast-iron pipe. This recess then receives the spigot end of the next pipe. The joint is practically of the same style as the joint generally used for cast-iron pipe.

MATTE. Matte, also known as coarse metal, is a mixture of copper and iron sulphide obtained in the smelting of copper ore in a blast or reverberatory furnace.

MATTER. Matter may be defined as anything that occupies space and possesses weight, or is acted upon by gravity. According to the atomic theory, matter is made up of molecules and atoms. The *molecule* is the smallest particle of matter that can exist in a free state; in other words, it is the smallest particle of matter having the properties of the original substance. It is also the smallest division that can be conceived of as made by mechanical means, and is, therefore, taken as the physical unit. Molecules are, however, supposed to be made up of *atoms*, which are thought to be invisible and to have certain unchanging properties. See also Electron Theory.

Forms of Matter. — Matter is indestructible, although the form of a substance may be changed or the substance resolved into its elements. The force that holds the molecules together is known as the "chemical affinity," or the "chemical force." When the molecules are of the same kind, the force is termed "cohesion"; when the molecules are unlike, the force is termed "adhesion." The accepted theory is that the molecules are in a state of constant motion and that the amount of this motion determines the form of the substance. When the motion is so great that the attractive

force is almost entirely overcome, the molecules appear to repel one another, and fly apart, filling every portion of the space within which they are contained; the matter is then said to be a *gas*. It has been calculated that at ordinary temperatures the average velocity of the molecules in the air is about that of a rifle bullet as it leaves the gun. Ordinary gases are invisible. Although the term " vapor " is frequently given to all gases, it is usually restricted to the gaseous form of substances that at ordinary temperatures and pressures are liquids or solids. When there is less motion and the attractive force is so great as to hold the molecules loosely together, the body is said to be a *liquid*. In this state, the molecules readily change their relative positions, and, therefore, retain no definite form except that determined by the containing receptacle. When the attractive force is so strong that there is comparatively little motion among the molecules, the substance is said to be a *solid*.

MAXIMUM SHEAR THEORY. This theory states that the cause of an elastic limit and the criterion for the beginning of failure is the sliding of particles past each other due to shear, and that failure in ductile materials is due to this sliding and not to direct tension. Hence, any case of direct tension or compression produces a tendency to slide and the failure is due to this. According to some investigators, the maximum shear theory should be adopted to the exclusion of the maximum strain and maximum stress theories since it shows that failure by tension and failure by compression are really only different aspects of failure by shear. Failure means the beginning of sliding which is not recovered when the stress is removed and gives permanent set, thus indicating the " elastic limit." It follows, therefore, that the elastic limit will be the same for tension as for compression. This is true for steel and other ductile materials and is in itself a point of evidence in favor of the maximum shear theory. Cast iron has no elastic limit and the actions referred to do not occur, so that elastic failure does not exist in cast iron as called for by the maximum shear theory. See Stress Theories.

MAXIMUM STRAIN THEORY. According to the maximum strain theory of St. Venant, failure occurs when the maximum unit deformation or strain in the piece reaches a certain critical value; hence, the stresses as measured by deformation or the " true stresses " should be considered. In other words, this theory supposes that the thing which causes failure and which must be used as a criterion for safety is the amount of deformation or strain. See Stress Theories.

MAXIMUM STRESS THEORY. The maximum stress theory supposes that failure and elastic limit are purely matters of stress in a given direction regardless of the existence of stresses in other directions. That is to say,

if a stress of 30,000 pounds is the elastic limit for a simple stress in a testing machine, it will also be the elastic limit in any case of compound stresses if the stress in one direction is 30,000 pounds and regardless of the existence of lesser stresses, whether tension or compression, in directions at right angles. See Stress Theories.

MAXWELL. The " maxwell " is the unit of magnetic flux, and is equal to the amount of magnetism passing through a square centimeter of a field of unit density. The symbol by means of which the maxwell is generally designated is ϕ. In non-magnetic materials, the unit intensity of flux is the same as the unit intensity of field strength; hence, one maxwell per square centimeter in non-magnetic materials equals one gauss. In magnetic materials, the flux produced by the molecular magnets is added to the field strength.

MEAN EFFECTIVE PRESSURE. The *effective* pressure acting against the piston of a steam engine, is the difference between the pressure on the steam side of the piston and that on the exhaust side, or, in other words, the difference between the working pressure and the back pressure. This value varies throughout the stroke with the expansion of the steam. The mean effective or average pressure (M.E.P.) is obtained from an indicator card and is used to determine the *indicated horsepower* of an engine.

MEASUREMENT, ABSOLUTE SYSTEM. See Absolute System of Measurement.

MEASURING MACHINES. The measuring machine is an instrument of great precision that is used for measuring standard lengths and for verifying the accuracy of reference gages. The ordinary type of measuring machine is provided with a rigid cast-iron bed upon which is mounted two heads, each of which contains a spindle that is placed in contact with the part to be measured. One head is equipped with a micrometer screw and a large graduated wheel or dial which indicates length variations within a limited range. For greater lengths, one head is moved along the bed the required distance. This movable head may be set by simply placing a standard end-measuring gage of known length between the contact points, or it may be set by reference to a standard bar forming part of the machine. Such a bar has extremely fine division lines which are equally spaced and enable the head to be accurately set by observing the lines through a suitable microscope. Another feature common to high-grade measuring machines is some form of mechanism for indicating the pressure of the contact or measuring points against the work, in order that slight errors will not be introduced in the measurements of duplicate parts, on account of minute variations in the pressure. Pressure indicating devices are made in several

forms, such as a plug which drops from between points when a certain pressure is reached; a level which is inclined at an angle when acted upon by the moving contact point; and a spring-operated plunger which is used in conjunction with a scale and hair-line microscope.

MECHANICAL DRAFT. Mechanical draft is often employed as a substitute for a tall chimney, and also in case a boiler plant is increased beyond the capacity of the original chimney. Again, certain kinds of low-grade fuels require a stronger draft than is provided by a chimney of ordinary height. Forced draft is also necessary for mechanical stokers of the under-feed type. In a general way, the advantages of mechanical draft are as follows: Increase of boiler capacity, as well as efficiency, which is due to the more intimate mixture of the air with the fuel, when under pressure, thus making it possible to carry deeper fires; ease of regulation, and the ability to provide just the right amount of air for complete combustion; the use of poorer grades of fuel than can be burned with a natural draft; and the possibility of forcing the boilers, if necessary, without regard to outside weather conditions. Forced draft also permits the use of feed-water heaters in the smoke flues, which cool the chimney gases to a comparatively low temperature, and which would interfere with the natural draft of a chimney. The cost of the equipment for mechanical draft is also considerably less than for a chimney.

MECHANICAL DRAWING PRINCIPLE. See Projection.

MECHANICAL EFFICIENCY. See Efficiency of Mechanism.

MECHANICAL EQUIVALENT OF HEAT. This is an expression used to designate the number of foot-pounds of mechanical energy equivalent to one British thermal unit. The mechanical equivalent of heat equals 778 foot-pounds.

MECHANICAL MIXTURE. A mechanical mixture is a substance composed of two or more other substances which are not combined chemically with each other; the particles of each ingredient can be identified and separated by mechanical means. See also Compound.

MECHANICAL POWERS. The five "mechanical powers" were defined in the old books on mechanics as the lever, the screw, the wedge, the inclined plane and the pulley. The wedge, the inclined plane and the screw are the same in principle. A screw is simply a cylinder with an inclined plane wrapped around it and, of course, an inclined plane and a wedge are the same. The pulley is but another form of the lever; hence, there are really only two so-called mechanical powers: the lever and the wedge or inclined plane.

MECHANICAL STOKERS. A material saving in labor can usually be effected by the installation of mechanical stokers in large and medium-sized power plants, as compared with hand firing. The cost of maintenance and initial cost of grates for hand firing is less than for mechanical stokers, but the coal is fed uniformly by mechanical stokers, which insures constant temperature and steaming. With hand-fired boilers, the furnace doors are opened frequently, which tends to chill both the fire and the furnace setting and is conducive to the production of smoke. Unless skilled firemen are employed, the efficiency of the hand-fired boiler will be lower, because of the greater heat content in the ash, holes in the fire bed, etc. Skilled firemen are also essential for mechanical stokers; but there are not so many required, and the men have more time to use efficient firing methods. Mechanical stokers may be divided into three general classes: The *chain-grate* stoker, which carries the green coal in the combustion chamber on a horizontal surface and depends upon the reflected heat from the brick arch above it to ignite it; the *inclined-grate* or *over-feed* stoker, which depends on the green coal feeding down over the fire bed, and the *under-feed* stoker, which forces the green coal in under the fire bed and utilizes forced draft. There are numerous designs of each of these classes.

MEDIUM PRESSURE. The expression "medium pressure," when applied to valves and fittings, means suitable for a working pressure of from 125 to 175 pounds per square inch.

MEGADYNE. Megadyne is a unit of force in the absolute system of measurement, equal to 10,000,000 dynes.

M.E.P. An abbreviation commonly used for Mean Effective Pressure.

MERCURY. Mercury, also known as quicksilver, is used mainly in the manufacture of fulminate for explosive caps, of drugs, of electric appliances, of alloys or amalgams, and of scientific apparatus, and, to a diminishing degree, in the recovery of precious metals, especially gold. Mercuric oxide (red oxide of mercury) is the active poison in antifouling paint used on ship's bottoms. Mercury dissolves a great many of the metals, forming with them alloys which are known as *amalgams*. Mercury occurs in nature mainly in the form of a red sulphide called "cinnabar" (HgS). Mercury is one of the metallic chemical elements, the symbol of which is Hg, and the atomic weight, 200.6. This metal is fluid at ordinary temperatures. It becomes a solid at −39 degrees C. (−38 degrees F.), and boils at 357 degrees C. (675 degrees F.). Mercury is one of the heavier metals, its specific gravity being 13.6, making the weight per cubic inch close to one-half pound. Its electric conductivity is low, being only about 1.75 (silver = 100). Its specific heat at 32 degrees F. equals 0.033, and its heat conductivity, 1.48 (silver = 100).

MERCURY AGOMETER. This is an instrument used for measuring electrical resistance or for varying the resistance of a circuit by means of an adjustable mercury column.

MERCURY BEARING METAL. An ideal bearing metal is one that will continue to function normally the maximum length of time under any adverse condition, such for example, as would result from the complete failure of the oil film. Mercury bearing metal is said to possess desirable characteristics of this kind, as repeated tests have demonstrated that seizure between the shaft and the bearing will not occur even though the bearing is used for a long period without any lubrication whatever. Mercury metal is an alloy in which a soft plaster matrix of metal is held by a web of tougher metal, which, in running, tends to adjust itself to the minute irregularities of the shaft. The tensile strength of mercury metal is approximately 23,000 pounds per square inch, and the compression strength, 92,000 pounds per square inch. This metal is applicable wherever plain bearings are used.

MERCURY DEPOSITS. The largest and richest known deposits of mercury in the world are located in central Spain, and there are large deposits in California and Texas. Deposits are also found in Russia, Bavaria, Hungary, Italy, Mexico, and Peru. The Spanish deposits have been mined almost continuously since the early Roman Empire, and have been owned and worked by the Spanish Government since 1645. The mines are now worked to a depth of more than 2000 feet, and the available reserve of mercury is estimated to be at least 40,000 tons of metal.

MERCURY-VAPOR LAMPS. See Vapor Lamps.

MERCURY-VAPOR POWER GENERATION. In the Emmet mercury-vapor process mercury is vaporized in a boiler at temperatures which can be much higher than those which are practicable with steam. It is then carried through a turbine and does useful work, exhausting into a surface condenser where its latent heat is used to make steam at pressures desirable for use. The condensed liquid is carried back to the boiler preferably by gravity. The characteristics of mercury are such that high temperature can be used without excessive pressure, and the heat of condensation can be delivered at a convenient degree of vacuum and at a temperature suited to making steam at pressures desirable for power uses. The process thus affords means by which the temperature ranges practicable with steam are greatly increased under conditions which afford large gains in efficiency of conversion of the heat energy of fuel into work.

The most difficult and novel part of this process is the boiler. While mercury is a good heat conductor, it does not wet steel and considerable temperature differences are required to deliver heat to it at a high rate.

When it begins to produce vapor on the heating surfaces this condition becomes rapidly worse. Successful mercury boilers are dependent upon a rapid circulation of the liquid and the large difference of pressure between the top and the bottom which prevents boiling of the circulating liquid until it is well started on its upward course. That is, the rapid heat delivery must be confined to the part of the surface which is not much disturbed by boiling. Rapid circulation is essential and the spaces for discharging vapor must be so proportioned that the circulation will not be checked by the escape of the vapor. If these spaces are too small the liquid will be given motion like a charge of shot, and prohibitive back pressure will result which will check circulation. The vapor must slip by the liquid, impelling it but not giving it too much velocity. Probably the most economical method of operating this process is to get as much heat as possible into the feedwater by bleeding the steam turbines as in modern steam practice.

MESSENGER STRAND. A messenger wire or strand is a wire or cable strung along with and supporting wires, cables, or other conductors for electric current. A seven-wire galvanized strand is used for supporting lead-covered telephone cables. The heavy lead-encased telephone wire cables are not, in themselves, sufficiently strong to withstand the strain incidental to stringing those cables between poles a considerable distance apart. A wire rope of $\frac{5}{16}$, $\frac{3}{8}$, or $\frac{7}{16}$ inch diameter, known as "messenger strand," is, therefore, strung between the poles, and the heavy telephone cable is suspended from this by means of clips, wire, or cord at short intervals.

METACENTER. See Buoyancy.

METAL. A metal is a chemical element which generally has a peculiar luster, known as "metallic" luster, is electropositive, is a conductor of heat and electricity, and usually occurs in nature in the form of compounds called ores. There is no very definite line drawn between the metals and non-metals. The elements which are not definitely classified as either the one or the other are known as "metalloids."

METALAYER. The trade name of a tool used for coating metals and other materials by spraying molten metal against the surface which is to be covered either to protect it, to build it up, or to secure an ornamental effect. See Metal Coating by Spraying Process.

METAL COATING BY SPRAYING PROCESS. A process of coating metals or other materials by spraying molten metal against the surface to be coated, makes it possible by means of a simple apparatus to apply a durable coating of any commercial metal upon any other metallic or non-metallic surface. Thus, any of the non-ferrous metals can be applied to ferrous metals, or this order may be reversed. Metallic coatings may also be applied

to non-metallic materials, such as wood, stone, brick, glass, porcelain, concrete, leather, and fabrics. The thickness of the coating may be varied, according to requirements, from 0.001 inch up.

The metal to be deposited upon a surface is used in the form of ordinary commercial wire if the standard apparatus is used. For some special purposes, metal dust or powder may be used instead of wire by employing a different form of apparatus, but this method is used to a very limited extent. The wire, which enters the tool at the rear, is fed automatically from a reel through the nozzle and into contact with an oxy-acetylene flame which melts the wire and, in combination with compressed air, blows the atomized metal against the surface being coated at a velocity of about 3000 feet per second. The metal, as it impinges against the surface at this high velocity, solidifies and practically becomes an integral part of the surface, as indicated by the fact that it cannot be separated from it either by severe hammering or bending tests.

This tool or torch, which is known as "Metalayer," is connected by a rubber hose to standard acetylene and oxygen cylinders and also to a supply of compressed air. The tool contains a compact wire-feeding mechanism, which is rotated by a small air turbine through suitable reduction gearing. This feed mechanism pulls the wire from the reel and feeds it through the nozzle at a rate varying usually from twelve to twenty-four feet per minute, depending upon the kind of metal used in coating. The wire remains unaltered and nearly cold until it reaches a point about $\frac{3}{32}$ inch beyond the nozzle. At this point the wire enters a reducing flame, and the minute particles of the molten spray are protected against oxidation so that layer after layer may be deposited, if desired, the entire coating forming a coherent and adherent mass. About 15 cubic feet of each gas is consumed per hour and approximately 50 cubic feet of compressed air per minute, the pressure of the latter being about 50 pounds per square inch.

METALLIC PACKING. Metallic packing is extensively used on steam engines to prevent any leakage of steam past the piston and valve stem, as it is much more durable than any fibrous packing, if the composition of the packing rings is correct and it is properly applied.

METALLOGRAPHY. The science or study of the microstructure of metal is known by most metallurgists as "metallography." The name "crystallography" is also used to some extent. The examination of metals and metal alloys by the aid of the microscope has become one of the most effective methods of studying their properties, and it is also a valuable means of controlling the quality of manufactured metallic articles and of testing the finished product. In preparing the specimen to be examined, a flat surface is first formed by filing or grinding, and this surface is then given

a high polish, which is later subjected to the action of a suitable acid or etching reagent, in order to reveal clearly the internal structure of the metal when the specimen is examined under the microscope. This process shows clearly to an experienced observer the effect of variation in composition, heat-treatment, etc., and in many cases it has proved a correct means of determining certain properties of industrial products that a chemical analysis has failed to reveal.

Preparing Hardened Steel for Microscopic Study. — To cause the constituents of the specimen to contrast with one another as seen through the microscope is the desired end, and a reagent is used which acts differently towards these elements; generally this reagent acts on one element more than on another so that the one least affected reflects the light from the faces of its crystals while the etched part absorbs the light and, therefore, appears dark when photographed.

In etching specimens to develop the constituents of hardened and tempered steels, very good results are obtained with sulphurous acid that is composed of 4 parts of sulphur dioxide to 96 parts of distilled water. The specimens are immersed in this, face upward, and removed as soon as the polished surface is frosted. This takes from 7 seconds to 1 minute. They are then rinsed with water and dried with alcohol. Very thin layers of iron sulphide are deposited on the different constituents in different thicknesses, and this gives them different colors. Austenite remains a pale brown; martensite is given a pale blue and deep blue and brown color; troostite is made very dark; sorbite is uncolored; cementite exhibits a brilliant white; and ferrite is made dark brown. When the etching has proceeded to the desired extent, the specimen is at once washed thoroughly in order to remove all trace of the etching reagent. Usually it is simply rinsed with water, but frequently the washing is done with absolute alcohol, while ether and chloroform are also sometimes used.

The apparatus used for examining the etched surfaces of metals is composed of a microscope and camera combined with an arc lamp or other means of illumination.

Microscopic Study of Steel. — Steel, in particular, shows many changes of structure due to the mechanical and thermal treatment, so that the microscope has become a very valuable instrument with which to inspect steel. To one who understands what the different formations of crystalline structure denote, the magnified surface reveals the temperature at which the steel was hardened, or at which it was drawn, and the depth to which the hardness penetrated. It also shows whether the steel was annealed or casehardened, as well as the depth to which the carbon penetrated. The carbon content can be closely judged, when the steel is annealed, and also how much of it is in the graphitic state in the high carbon steels. The quantity of special

elements that is added to steel, such as nickel, chromium, tungsten, etc., can also be estimated, when the alloy to be examined has been put through its prescribed heat-treatment. Likewise, the impurities that may be present are clearly seen, regardless of whether they are of solid or gaseous origin.

METALLOIDS. Metalloids are chemical elements on the borderline between the two main classes of elements — metals and non-metals. The metalloids as a rule resemble metals in their physical properties and non-metals in their chemical properties.

METALLURGY. The art of extracting metals from their ores is, in general, known as *metallurgy*, but the term has, by custom, been restricted to the commercial methods used, as opposed to those which are employed only in the laboratory. When the metals are extracted from their ores by means of electrical processes, the art is known as *electrometallurgy*. Briefly stated, the metals are obtained from their ores by one of three methods: 1. By being exposed to the action of fire in the presence of a flux, so as to burn away certain components of the ore, or deoxidize (" reduce ") it. 2. The ore may be amalgamated by mercury, so that the metal is obtained as an amalgam, which can be separated mechanically from the dross. The purified amalgam is distilled and the mercury is recovered as a distillate, while the metal remains. 3. The wet process, in which the metal is extracted either from the natural ore or from the ore after it has been roasted, by means of an acid or salt solution, and precipitated from this solution by some suitable reagent. All of these methods generally yield an impure product, which must be refined before it becomes a commercial market product.

METER EQUIVALENT IN LIGHT WAVES. See Light Wave as Length Standard.

METER-KILOGRAM. This is a unit of work in the metric system, designating the work required to raise one kilogram to a height of one meter; 1 meter-kilogram = 7.233 foot-pounds.

METERS, AMPERE-HOUR. See Ampere-hour Meters.

METERS AND INSTRUMENTS. Although the terms " instruments " and " meters " are frequently used synonymously in referring to electrical measuring devices, the meter departments of manufacturing and operating companies commonly use the word " meters " in the collective sense to designate only those devices which register the total energy or quantity of electricity consumed in or supplied to a circuit, and reserve the term " instruments," in the collective sense, for all other electrical measuring or indicating devices.

METRIC HORSEPOWER. The unit of power adopted for engineering work, as defined in the English system of measurement, is equal to 33,000 foot-pounds per minute, or 550 foot-pounds per second. The metric horsepower, used in countries where the metric system is employed, is equal to 75 kilogram-meters per second, which is only 32,550 foot-pounds per minute, or 542.5 foot-pounds per second. Hence, it is evident that the metric horsepower is about 1.5 per cent smaller than the horsepower employed in the countries using the English system of measurements.

METRIC SYSTEM. In the metric system of measurements, the principal unit for length is the meter; the principal unit for capacity, the liter; and the principal unit for weight, the gram. The following prefixes are used for subdivisions and multiples: milli = $\frac{1}{1000}$; centi = $\frac{1}{100}$; deci = $\frac{1}{10}$; deca = 10; hecto = 100; kilo = 1000. In abbreviations, the subdivisions are frequently used with a small letter and the multiples with a capital letter, although this practice is not universally followed everywhere where the metric system is used. All the multiples and subdivisions are not used commercially. Those ordinarily used for length are kilometer, meter, centimeter, and millimeter; for capacity, square meter, square centimeter, and square millimeter; for cubic measures, cubic meter, cubic decimeter (liter), cubic centimeter, and cubic millimeter. The most commonly used weights are the kilogram and gram. The metric system was legalized in the United States by an Act of Congress in 1866.

Metric Measures of Length. — 10 millimeters (mm.) = 1 centimeter (cm.); 10 centimeters = 1 decimeter (dm.); 10 decimeters = 1 meter (m); 1000 meters = 1 kilometer (Km.).

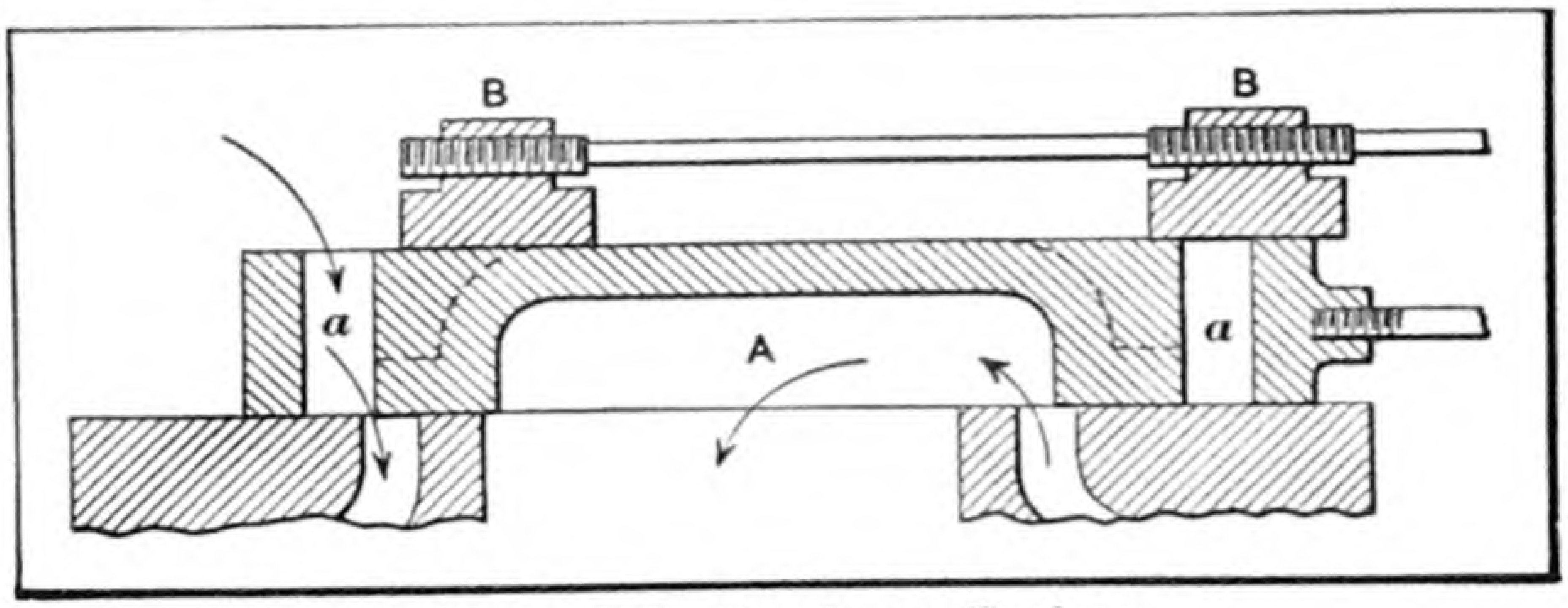
Metric Measures of Weight. — 10 milligrams (mg.) = 1 centigram (cg.); 10 centigrams = 1 decigram (dg.); 10 decigrams = 1 gram (g.); 10 grams = 1 decagram (Dg.); 10 decagrams = 1 hectogram (Hg.); 10 hectograms = 1 kilogram (Kg.); 1000 kilograms = 1 (metric) ton (T.).

Metric Weight Equivalents. — 1 metric ton = 0.9842 ton (of 2240 pounds) = 2204.6 pounds; 1 kilogram = 2.2046 pounds = 35.274 ounces avoirdupois; 1 gram = 0.03215 ounce troy = 0.03527 ounce avoirdupois; 1 gram = 15.432 grains.

METRIC TRANSLATING GEARS. See Translating Gears.

MEYER VALVE. This form of engine slide valve is commonly known as the *riding cut-off* type; it is used for producing a sharp cut-off which shall be independent of the other events of the stroke. An ordinary slide valve *A* (see illustration), has two ports *a*. On top of this main valve are two cut-off valves *B* attached to a common rod. The main valve and the cut-off valves are driven by independent eccentrics. The latter are set so that, at the time of cut-off, the rider valves are traveling in a direction opposite to that

of the main valve, thus producing a sharp cut-off with but little "wire drawing." One of the other advantages of this type of valve is the ease of regulation, the governor being attached to the rider valves which are of light



Meyer Valve for Steam Engines

weight and very responsive, therefore requiring but little power to operate them.

MICA. There are two industrial varieties of mica. One is "muscovite" (commercially known as rum, ruby, smoked, or green, according to its color) and the other "phlogopite" (amber). Only muscovite is mined on an extensive scale in the United States. Phlogopite comes from Canada and India, large quantities being imported into the United States. The chief mines in the United States are in North Carolina. The most extensive application of mica is for electrical purposes, because it is one of the best insulators available. The fact that it is able to withstand high temperatures also makes it valuable as an insulating material for electrical machinery. The laminas of mica are generally separated and sorted into various grades of purity, and are then cemented together to form plate or flexible reconstructed mica of any required thickness or purity. Mica is extremely complex and variable in composition. It generally consists of an anhydrous silicate of aluminum together with potash or sodium. Mica is characterized by a very easy cleavage in a single direction, and by a high degree of flexibility, elasticity, and toughness.

MICA INSULATION OF COMMUTATORS. See Commutator Insulation.

MICARTA. Micarta is a non-metallic laminated product of specially treated woven fabric. By means of the various processes through which it is passed, it becomes a homogenous structure with physical properties which make it especially adapted for use as gears and pinions. Micarta can be supplied either in plate form or cut into blanks. It may also be molded into rings or on metal hubs for applications such as timing gears, where quantity production is attained.

Micarta gears do not require shrouds or end plates except where it is desired to provide additional strength for keyway support or to protect the keyway and bore against rough usage in mounting drive fits and the like. When end plates for hub support are employed they should extend only to the root of the tooth or slightly less.

Properties. — The physical and mechanical properties of Micarta are as follows: Weight per cubic inch, 0.05 pound; specific gravity, 1.4; oil absorption, practically none; shrinkage, swelling or warping, practically none up to 100 degrees C.; coefficient of expansion per inch per degree Centigrade, 0.00002 inch in the direction parallel to the laminations (edgewise), 0.00009 inch in the direction perpendicular to the laminations (flatwise); tensile strength, edgewise, 10,000 pounds per square inch; compressive strength, flatwise, 40,000 pounds per square inch; compressive strength, edgewise, 20,000 pounds per square inch; bending strength, flatwise, 22,000 pounds per square inch; bending strength, edgewise, 20,000 pounds per square inch. Micarta may be machined in the ordinary manner with standard tools and equipment.

MICARTA MACHINING. In cutting blanks from sheets of "micarta" a band saw running at a speed of 350 revolutions per minute has been found suitable. The saw should be of the bevel-tooth type, seven teeth to the inch. For large quantities a trepanning tool should be used. In trepanning blanks, the tool should be fed so as to cut part way through all of the "layouts"; then the micarta plate should be turned over, and the cutting completed from the reverse side.

Turning tools should be of high-speed steel cutting at speeds similar to those used for bronze or cast iron. If two cuts are taken, about 0.010 inch of stock should be left for the finishing cut.

Drilling at right angles to the layers is done with a standard drill, which should be backed off sufficiently to provide plenty of clearance. When drilling parallel to layers, a "flat" or "bottom" drill should be used. In rough-drilling, the hole should preferably be drilled partly through the material from each side to prevent possible splitting as the tool protrudes. If this is impracticable, the hole can be drilled all the way through the material, provided the material is "backed up" with wood, stiff cardboard, or any other material that is sufficiently rigid to support the under surface at the point where the drill comes through.

The methods described for drilling apply as well to tapping, except that when the tapping is done parallel to the layers, it is advisable to clamp the material to equalize the stress on the layers and prevent possible splitting.

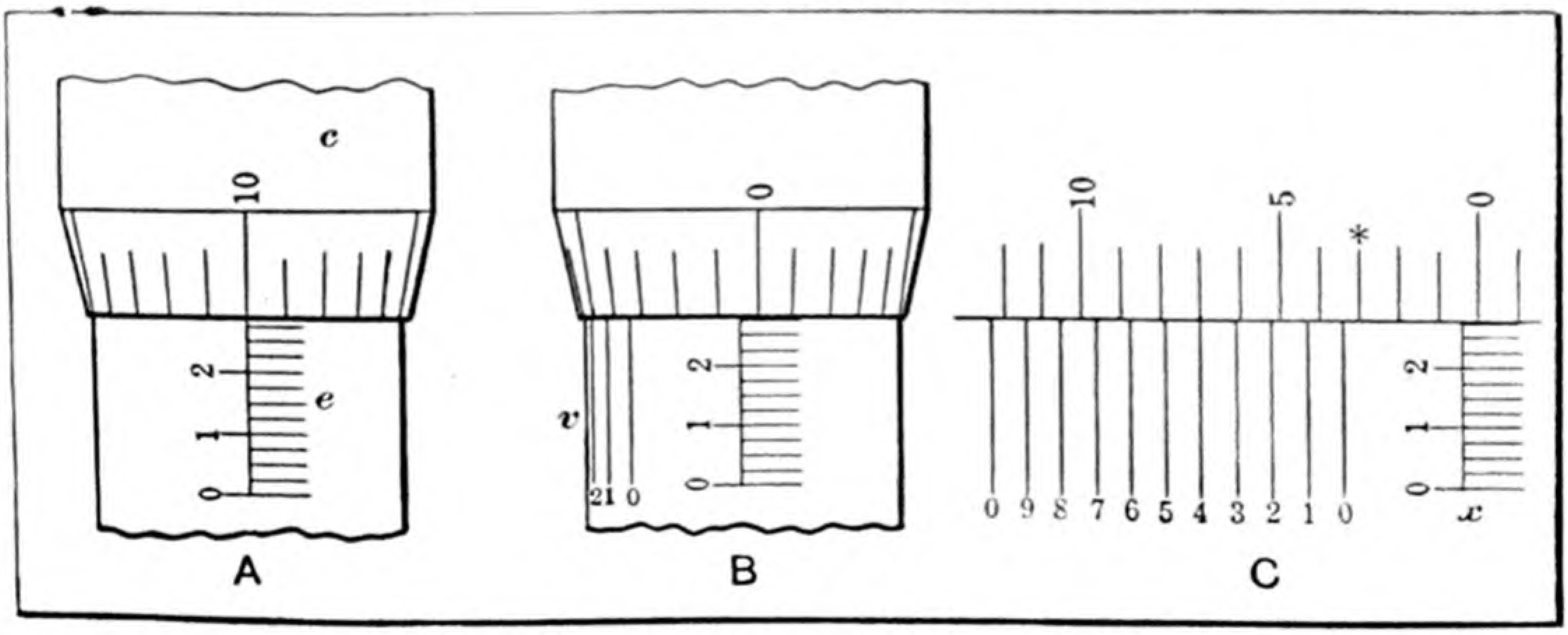
In milling, a standard tool may be used at a speed and feed corresponding to that used in working bronze or soft steel. The cutting angle of the cutter will give better results if ground with a slight rake.

While there is a wide range of practice as to feeds and speeds in cutting gears on hobbing machines, a hob speed of not less than 140 revolutions per minute, has given satisfaction. In machining gear teeth on a gear shaper, a speed of about 100 to 130 strokes per minute with a fairly fine feed has given good results. Backing-up plates should be used in machining micarta gears.

MICO-IRON. Mico-iron is an iron of close grain, uniform texture, said to have long wearing qualities and considerable strength, and to be especially suitable for castings for machine tools, gas engines, air compressors, gears, high-pressure valves, and rolling mills. It can be readily machined, and surfaces requiring long life can be chilled without affecting the machineability of other surfaces. The tensile strength of "Mico" cast iron is from 32,000 to 35,000 pounds per square inch.

MICRO-COULOMB. See Coulomb.

MICROMETER. Micrometer calipers are precision measuring instruments that are equipped with a screw of fine pitch and graduations which



Micrometer Graduations

show slight movements of the screw so that accurate measurements can be taken. The pitch of the thread on the spindle of an ordinary micrometer is $\frac{1}{40}$ of an inch. Along the frame at *e* (see diagram *A*), there are graduations which are $\frac{1}{40}$ inch apart; therefore, when thimble *c* and the measuring spindle are turned one complete revolution, they move in or out a distance equal to one of the graduations, or $\frac{1}{40}$ inch, which equals $\frac{25}{1000}$ inch. If, instead of turning one complete revolution, the thimble is turned, say, $\frac{1}{25}$ of a revolution, the distance between the anvil and the end of the spindle will be increased or diminished $\frac{1}{25}$ of $\frac{25}{1000}$ of an inch, or one thousandth inch; therefore, the beveled edge of a micrometer spindle has twenty-five graduations, each of which represents 0.001 inch. Some micrometers have a vernier

scale v on the frame, as shown at B, in addition to the regular graduations, so that measurements within 0.0001 inch can be taken. Micrometers of this type are read as follows: First determine the number of thousandths, as with an ordinary micrometer, and then find a line on the vernier scale that exactly coincides with one on the thimble; the number of this line represents the number of ten-thousandths to be added to the number of thousandths obtained by the regular graduations. The relation between the graduations of the vernier and those on the thimble is more clearly shown by diagram C.

MICROMETER CALIPER'S ORIGIN. Evidence which is now available shows that credit for the origin of the micrometer caliper must be largely accorded to a French inventor and machinist by the name of Jean Laurent Palmer, who was working at the time in Paris. Palmer's "screw caliper," as he called it, was patented in France on September 7, 1848, and was manufactured under the name of the "Systeme Palmer." There did not seem to be any general appreciation of the importance of this tool until the year 1867, when it was seen by Joseph R. Brown and Lucian Sharpe, while on a visit to the Paris Exposition of that year. They were impressed with the possibilities of such a tool when properly made, and brought one back with them on their return to America. Soon after, they commenced the manufacture of a small-sized micrometer, suitable for measuring sheet metal and wire, placing it on the market in 1869 under the name of the "pocket sheet-metal gage." The introduction of the 1-inch micrometer caliper followed that of the pocket sheet-metal gage, and it was shown in the Brown & Sharpe catalogue of 1877, and for the first time, the name "micrometer caliper" was used.

MICRO-PHOTOGRAPHY. See Photomicrography and also Metallography.

MICROSCOPE, TOOLMAKER'S. See Toolmaker's Microscope.

MICROSCOPIC EXAMINATION OF STEEL. See Metallography.

MIL AND CIRCULAR MIL. The *mil* is used in the measurement of the diameters and areas of electric wires, and the thicknesses of electrical insulating materials. A mil equals 0.001 inch. A *circular mil* is the area of a circle 0.001 inch in diameter. See also Circular Mil.

MILE. One mile = 1760 yards = 5280 feet = 1.609 kilometer = 1609 meters. As a surveyor's length measure, one mile = 8 furlongs = 80 chains = 1760 yards = 5280 feet. A nautical mile, sometimes incorrectly called "knot," equals 1.1516 statute miles or 6080.26 feet. A *knot* is a measure of speed, and is equal to a speed of one nautical mile per hour.

MILL FILE. Mill files are parallel in thickness from the heel to the point and usually tapered so that the width at the end equals about three-fourths

the width of the stock. The mill file is also made " blunt " or of equal width and thickness throughout its length. Quite a number of mill files having one round edge are used, and some are provided with two round edges. The teeth are ordinarily single-cut, bastard. This file is used in machine shops for lathe work, draw-filing, and, to some extent, for filing brass and bronze. It is also employed for sharpening metal saws, etc. The mill files of the round edge type are used for filing the gullet or space between saw teeth.

MILLING, CONTINUOUS. See Continuous Milling.

MILLING CUTTERS. As the processes of milling can be applied to an almost unlimited range of work, the cutters used on milling machines are made in a great variety of forms. Some of the different types can be used for general work of a certain class, whereas other cutters are made especially for milling one particular part. A cylindrical or plain cutter is used for producing flat surfaces and it is made in various diameters and lengths. Cutters having helical teeth are generally used in preference to the type with straight or parallel teeth, especially for milling comparatively wide surfaces, because the former cut more smoothly. Helical cutters also require less power for driving and produce smoother surfaces.

A side milling cutter has teeth on both sides, as well as on the periphery, and it is used for cutting grooves or slots and for other operations, examples of which will be shown later. Two side mills are often mounted on the same arbor and used in pairs for milling both sides of a part at the same time. This type of cutter is also employed in conjunction with other forms for milling special shapes. The inserted-tooth construction is used ordinarily for large cutters, in preference to the solid form, because it is cheaper, and the inserted teeth can readily be replaced when necessary. When solid cutters are made in large sizes, there is danger of their cracking while being hardened, but with the inserted-tooth type, this is eliminated.

End mills have teeth on the end as well as on the periphery or body; hence, they can cut in an endwise as well as a sidewise direction. These mills have taper shanks which are driven into a hole of corresponding taper in the machine spindle. The shanks have a flat end or tang which engages a slot in the spindle and prevents the mill from slipping when taking a cut. The larger sizes of end mills do not have solid taper shanks, but are made in the form of shells which are fastened to an arbor that serves as a shank. This type of cutter can often be used when a long arbor with an outboard support would be in the way. Formed milling cutters are made to the same shape as the profile of the piece to be milled.

MILLING CUTTERS, HAND OF. A cutter which rotates to the right (clockwise), as viewed from the spindle or rear side, is said to be right-hand,

and, inversely, a left-hand cutter is one that turns to the left (counter-clockwise) when viewed from the spindle of the machine.

MILLING MACHINE LEAD. See Lead of Milling Machine.

MILLING MACHINE ORIGIN. The first practical machine for plain milling operations is said to have been built by Eli Whitney, well-known inventor of the cotton gin, about 1818. This machine, now in the possession of Yale University, is a small bench type. A solid wooden block forms the base of the Whitney milling machine and the supporting legs are made of wrought iron. The main spindle is driven directly by a belt pulley, and between the two main spindle bearings there is a double-grooved wooden pulley connecting with a smaller pulley on a worm-gear shaft of the feed mechanism. The worm of this shaft engages a worm wheel mounted upon the table feed-screw. This worm is held in engagement by a spring latch which permits disengagement for hand feeding. The worm shaft is pivoted at one end so that the worm could readily drop out of engagement.

MILLING MACHINES, ATTACHMENTS. The range of a milling machine, or the variety of work it is capable of doing, can be greatly extended by the use of special attachments. Many of these are designed to enable a certain class of milling machines to perform operations that ordinarily would be done on a different machine; in other words, the attachment temporarily converts one type of machine into another. There are many different attachments for milling machines, some of which are very common, whereas others are rarely used in the average shop.

Vertical-spindle Attachments. — Vertical attachments are used in connection with horizontal machines of the column-and-knee types, whenever it is desirable to have the cutter in a vertical or angular position. There are several types of vertical attachments designed for various classes of work. The principal difference between these designs, aside from minor details, is in the adjustment of the cutter spindle.

Compound Vertical-spindle Attachment. — There is a compound type of vertical spindle attachment which is adjustable in two vertical planes, one being parallel with the axis of the spindle, and the other being at right angles to the spindle.

Universal Milling Attachment. — The universal milling attachment is so named because the spindle can be set at any angle in both horizontal and vertical planes.

Spiral Milling Attachment. — When milling a spiral, it is not always possible to align the cutter with the angle of the spiral by swinging the machine table around. The tables of most universal milling machines cannot be adjusted to an angle greater than about 45 or 50 degrees; hence, for greater angles it is common practice to leave the table in its normal position

at right angles to the spindle of the machine, and to use an attachment for holding the cutter at the proper angle. What are known as spiral milling attachments are often used for this work, and they are so arranged that the cutter spindle may be swiveled to any angle in a horizontal plane.

High-speed Attachment. — For some milling operations on such work as diemaking, etc., it is necessary to use a small cutter which should be run more rapidly than the fastest spindle speed available, and, in order to obtain these high speeds, special attachments are sometimes used. These attachments consist principally of an auxiliary spindle that holds and drives the cutter, and suitable gearing connecting with the main spindle and so proportioned as to give the necessary increase of speed. The gearing and spindle are carried by a housing which is attached to the machine. High-speed attachments are used on both horizontal- and vertical-spindle machines.

Circular Attachment. — A circular milling attachment has a round work table which can be rotated for milling circular surfaces or slots. This attachment, which is placed upon the main table of the machine, is either used on a vertical-spindle machine or in connection with a vertical-spindle attachment on a horizontal-spindle machine.

MILLING MACHINES, CLASSIFICATION. The names used to designate different classes of milling machines may indicate some constructional feature that is characteristic, or they may relate to the nature of the work for which the machine is intended. There are a few exceptions to this method of classification, however, as special names are used to some extent; moreover, in some cases, manufacturers of milling machines do not use the same name for similar types of machines. The constructional features which are generally indicated by the name are the position of the spindle, the design of the bed or frame, and the arrangement of the work table. A great many milling machines have horizontal spindles, and some of them are known as *horizontal* types, but, in most cases, the name indicates some other constructional feature in order to distinguish between different classes having horizontal spindles. For instance, there are *plain* machines and *universal* machines; both of these types have horizontal spindles, but one is simpler in construction than the other and is not adapted to such a wide range of work. A vertical milling machine has a vertical spindle; some special vertical milling machines, however, are named according to the class of work for which they are intended, as, for example, die-sinking and profiling machines, which are, in reality, special types of vertical spindle milling machines.

The frames of milling machines are usually of two general forms; the most common design is a vertical column which supports the horizontal cutter spindle, and has on the front face or side an adjustable knee upon which the

work-table is mounted. This is known as the *column-and-knee* construction; several different types of milling machines are designed in this way. Other milling machines have beds or frames which extend horizontally like the bed of a planer, instead of vertically. The design of the bed in any case is governed partly by the position of the spindle, and it is also affected largely by the general requirements of the work for which it is intended; for instance, milling machines which are used for milling long surfaces and for doing the same general class of work which is done on planers must have a long horizontal bed and work table, with the necessary feeding movements. Such machines are often known as the *horizontal* or *planer* type.

MILLING MACHINES, HAND TYPE. The hand milling machine is so named because the table or cutter is fed by hand instead of by an automatic power feed. A typical design is so arranged that the table can be fed in a lengthwise direction by a hand lever or by turning the feedshaft with a crank. The spindle head also has a vertical lever feed. This type of milling machine is adapted to short milling operations, especially when it is desirable to take light cuts which are not of sufficient length to warrant using a milling machine having an automatic feed. When the cuts are comparatively short, the surfaces can be milled quickly and easily by using a hand-operated machine. Quite a variety of milling is done on machines of this type. For some operations, a weight is suspended at the end of the feed lever and in this way an automatic gravity feed is obtained.

MILLING MACHINES, LINCOLN TYPE. The well-known Lincoln type of milling machine is named after George S. Lincoln of the firm then known as George S. Lincoln & Co., Hartford, Conn. Mr. Lincoln, however, did not originate this type but he introduced an improved design. Milling machines constructed along the same general lines had previously been built by the Phoenix Iron Works of Hartford, Conn., and also by Robbins & Lawrence Co., of Windsor, Vt. Milling machines of this class are intended especially for manufacturing and are not adapted to a great variety of milling operations, but are designed for machining large numbers of duplicate parts. Some milling machines which are designed along the same lines as the Lincoln type are referred to as the *manufacturing type*. The distinguishing features of the Lincoln type are as follows: The work table, instead of being carried by an adjustable knee, is mounted on the solid bed of the machine and the outer arbor support is also attached directly to the bed. This construction gives a very rigid support both for the work and the cutter. The work is usually held in a fixture or vise attached to the table, and the milling is done as the table feeds longitudinally. The table is not adjustable vertically but the spindle head and spindles can be raised or lowered as may be required.

MILLING MACHINES, PLAIN TYPE. This type of milling machine has a horizontal cutter spindle and is of the column-and-knee construction, which means that there is a vertical column, and a knee which is fitted to guiding ways on the face of the column, to provide vertical adjustment for the work table. The " plain " type differs from what is termed the " universal " type, in that the work table cannot be set at an angle relative to the spindle. Plain milling machines are commonly used for milling operations which can be performed by feeding the work in a straight line, either vertically or in a horizontal plane, although in modern practice there are many exceptions to this rule. In general, plain milling machines are adapted to a smaller range of work than the universal type, although many modern plain machines have attachments which greatly increase their working range. Ordinarily, plain machines are more rigid and heavier in construction than universal designs for a given size of machine, and are intended for heavier milling operations. The plain type is used principally for manufacturing operations, whereas the universal machine is intended more for tool-rooms and for a diversified line of work.

MILLING MACHINES, UNIVERSAL TYPE. The universal type of milling machine is so named because it is adapted to a very wide range of milling operations. The general construction is similar to that of a plain milling machine, although the universal type has certain attachments which plain machines do not ordinarily have, and which make it possible to mill a comparatively large variety of work. The universal machine has a knee which can be moved vertically on the column and a table with both cross and longitudinal movements, the same as a machine of the plain type; there is a difference, however, in the method of mounting the table on the knee. The table of a plain machine is carried by a saddle which is free to move in a crosswise direction, whereas the table's line of motion is at right angles to the spindle. The table of a universal machine also has these movements, and, in addition, it can be automatically fed at an angle to the spindle by swiveling the saddle on a lower base or " clamp-bed " which is interposed between the saddle and the knee. The circular swiveling base of the saddle has degree graduations which show the angular position of the table. This angular adjustment makes it possible to do work, such as helical milling, which could not be done on a plain machine unless a spiral milling attachment were used that provided the required angular adjustment for the cutter. Practically all universal machines are equipped with auxiliary appliances, such as the dividing or indexing head, vertical milling attachments, etc. Many of these same attachments are also used on plain milling machines which are thus converted, to some extent, into universal types. The first universal milling machine was designed and built at the works of the J. R. Brown & Sharpe Co., in 1861–62.

MILLING MACHINE, STANDARD SPINDLE. A standard spindle end for milling machines has been adopted by the milling machine manufacturers of the National Machine Tool Builders' Association for machines from 2 to 25 horsepower. The tapering bore for receiving arbors or cutter shanks has a taper of $3\frac{1}{2}$ inches per foot, this steep angle taper having been adopted to insure instant release of the arbor and eliminate sticking in the spindle. The large end of the arbor hole is $2\frac{3}{4}$ inches in diameter and it merges into a straight or cylindrical inner section having a diameter of $1\frac{9}{16}$ inches with plus and minus tolerance of 0.005 inch. The combined length of the tapering and straight sections is $5\frac{1}{2}$ inches minimum. The outside diameter of the spindle nose is 5.0613 inches minimum and 5.0618 inches maximum. A slot for large cutter driving extends across the spindle nose. This has a width of 0.9998 inch minimum and 1.0002 inches maximum, and a depth of 0.495 inch minimum and 0.505 inch maximum. There are four equally spaced tapped holes in the end of the spindle on a circle having a diameter of 4 inches with a plus and minus tolerance of 0.005 inch. These holes are $\frac{5}{8}$ inch in diameter, 11 threads per inch, and $1\frac{1}{8}$ inches deep. In conjunction with this standard there are five standardized sizes of treated arbors and ten plain arbors, and six shell end-mill arbors. These have been standardized in regard to important dimensions and method of designation.

MILLING MACHINE, TILTED ROTARY. In the design of this machine, provision is made for employing either the continuous rotary method of milling, or for applying an indexing principle of operation by which successive pieces of work are brought opposite the cutter, after which the ram that carries the spindle is advanced radially to feed the cutter across the work. By inclining the table at an angle, a better opportunity is afforded for the coolant to wash away chips. This inclined table also makes it possible to use an auxiliary reservoir in which the cutters and work can be submerged in a bath of coolant while the milling operation is performed. The term "sub-surface" milling has been applied to this method of cooling the milling cutters and work.

MILLING SCREW THREADS. See Thread Milling.

MILWAUKEE APPRENTICE TRAINING PLAN. This is a method for the systematic training of apprentices to supply the needs for skilled mechanics in an entire community. It was originated in Milwaukee, Wis., where most of the shops in the metal-working industries coöperate with each other in maintaining a uniform system of apprentice training. The large shops train their own apprentices completely in a four-year course, but if the shops are small, or their product highly specialized, so that the apprentice could not get a thorough training in one shop, the boys are exchanged or shifted from shop to shop, so that during a four-year term they

still acquire an all-around training. The plan was inaugurated about 1920 and the results have been very satisfactory. Several Milwaukee shops now depend wholly upon their apprentice graduates for skilled mechanics, as well as future foremen and shop executives.

MINERAL BLACK. This material, made by grinding certain kinds of slate, is used as a filler for paints employed for protecting iron and steel against corrosion.

MINERAL LARD OIL. For automatic screw machine work some manufacturers use pure lard oil, but here the need of a large volume of oil causes the question of economy to play an important part; as the so-called "mineral lard oil" mixtures, ranging from 30 per cent of lard oil and 70 per cent of medium petroleum oil up to equal parts of lard oil and petroleum oil, have been found to give practically as good results as pure lard oil, it seems desirable to use these mixtures. Furthermore, mineral lard oil has an advantage over pure lard oil in that it is more fluid and thus runs more freely to the tool and work; also, this mixed oil is not so likely to give trouble from gumming

MINERAL WOOL. Mineral wool is a fibrous substance made from blast-furnace slag by sending a blast of steam through the molten slag. This substance, sometimes known as "silicate of cotton," is used as a heat insulator and also as a fireproofing material. In the latter case, it is packed between the wall and floor spaces of fireproof buildings. Mineral wool may also be made by sending a blast of steam through molten rock. This "rock wool" should be used when the heat-insulating material is in contact with metal, as the sulphur in the slag wool is likely to cause corrosion. The best grades have a fine fibrous structure, and are fairly free from lumps. Variations in the character of the slag affect the grade of the wool, and there is usually a difference in the density of the wool at every cast. The method of producing mineral wool is briefly as follows: Blast-furnace slag and coke are charged into a cupola. The molten slag, at the moment when it flows through the slag hole, is then divided into fine threads by streams of steam. These fine threads are blown into a long narrow building, where the material is stored and packed.

MINER'S INCH. The term "miner's inch," used in western United States for measuring the flow of a stream of water, is more or less indefinite, because different values have been assigned to it; thus, the amount of water corresponding to a miner's inch varies from 1.36 to 1.73 cubic foot per minute, according to the method used for the measurement. The California Legislature, by an Act of 1901, prescribed that the miner's inch should be equivalent to 1.5 cubic foot of water per minute, measured through any

aperture or orifice. The most common measurement is through an aperture 2 inches high and through a plank $1\frac{1}{4}$ inches thick, the width of the aperture being whatever length is required. The lower edge of the aperture is placed 2 inches above the bottom of the measuring box and the plank is 5 inches high above the aperture, so that the head will be 6 inches above the center of the stream through the orifice. Each square inch of the opening represents a miner's inch, and the amount of water that will flow through it equals about $1\frac{1}{2}$ cubic feet per minute.

MINOFOR METAL. Minofor metal is a tin-antimony-copper alloy containing a large percentage of zinc. It belongs to the Britannia metal class, and contains, on an average, 68.5 per cent of tin, 18.2 per cent of antimony, 3.3 per cent of copper, and 10 per cent of zinc.

MINOR DIAMETER. The smallest diameter of the thread on the screw or nut is the "minor diameter." This term has been used to replace the term "core diameter" as applied to the thread of a screw and also the term "inside diameter" as applied to the thread of a nut. See also Major Diameter.

MITER GEARS. If the number of teeth in two bevel gears is alike, the gears are equal, the pitch-cone angle of each being 45 degrees, and the gears are commonly referred to as miter gears. All dimensions in the two gears are the same, and the gears are interchangeable.

MIXER. A mixer is a large tilting furnace, used in the Bessemer process, in which the molten pig iron from different heats in the blast furnace is held until needed for the converter, sufficient fuel being burned in the mixer to keep the iron hot. It is often heated by blast furnace or producer gas.

MO. This is a Japanese measure of weight, equal to 0.00375 gram, or 0.0579 grain. One mo equals 10 shis.

MODULE. The module, as referred to the metric system of gear teeth, is equal to the pitch diameter of a gear, in millimeters, divided by the number of teeth in the gear. In the metric system the dimensions of gear teeth are expressed by reference to the module of the gear. For example, if the pitch diameter of the gear is 50 millimeters, and the number of teeth, 25, then, according to the rule given, the module equals $50 \div 25 = 2$. The module is also equal to the circular pitch in millimeters divided by 3.1416. Both rules give the same result. The addendum equals one module and the dedendum, one module plus the clearance.

MODULUS OF ELASTICITY. The modulus of elasticity of an engineering material is the quotient obtained by dividing the stress per square inch by the elongation in one inch caused by this stress. This modulus is gener-

ally denoted by E. If an elongation of 0.030 inch is produced in a heat-treated alloy steel bar, 10 inches long, by a load of 90,000 pounds per each square inch of cross-section of the bar, then the modulus of elasticity is:

$$E = \frac{90,000}{0.003} = 30,000,000.$$

The elongation is assumed to be proportional to the load up to the elastic limit; hence, the modulus of elasticity of a material may be used for finding the elongation e produced by any load per square inch, S, by the formula: $e = S \div E$.

MODULUS, SECTION. See Section Modulus.

MOHS'S HARDNESS SCALE. Hardness, in general, is determined by what is known as Mohs's scale, a standard for hardness which is mainly applied to non-metallic elements and minerals. In this hardness scale there are ten degrees or steps, each designated by a mineral, the difference in hardness of the different steps being determined by the fact that any member in the series will scratch any of the preceding members. This scale, which was devised in 1820 by F. Mohs, for the purpose of expressing the hardness of minerals by numbers, is as follows:

1. Talc; 2. gypsum; 3. calcite; 4. fluor spar; 5. apatite; 6. orthoclase; 7. quartz; 8. topaz; 9. sapphire or corundum; 10. diamond.

These minerals, arbitrarily selected as standards, are successively harder, from talc, the softest of all minerals, to diamond, the hardest. This scale, which is now universally used for non-metallic minerals, is, however, not applied to metals as entirely different and more precise methods are employed.

MOISTURE IN COMPRESSED AIR. See Compressed Air, Moisture in.

MOISTURE IN LUMBER. See Lumber Water Content.

MOL. The term "mol" is used as a designation of quantity in electrochemistry, and indicates the number of grams of a substance equal to its molecular weight. For example, one mol of silver-nitrate equals 169.89 grams, the molecular weight of silver-nitrate being 169.89.

MOLDING. Molding is a process by which an impression or mold is formed in damp sand or other plastic material in such a way that it can be used as a form into which molten metal is poured to produce a casting corresponding to the shape of the impression or mold. Ordinarily a pattern is used to form the mold, and when the pattern is removed it leaves a cavity of the required shape, into which molten metal is poured. The sand or other

material for making molds for small and medium-sized castings is usually confined in molding boxes called flasks, while the molds for large pieces are made directly on the foundry floor which is provided with pits filled with molding sand to a depth of several feet. The smaller flasks are placed on benches of suitable height, and the men who specialize on small work are called " bench molders " to distinguish them from the men who do their work either on or in the floor, and who are known as " floor molders."

Green Sand Molding. — The green sand method of making molds is the most important branch of the molders' work, as the majority of castings are made by this method. The term " green sand " means that the mold is used at once or while in a green or damp condition. The interior surfaces of the mold are " skin-dried " in some cases.

Dry Sand Molding. — This branch of molding differs from green sand molding in that molds, after being made from damp sand, are dried or baked in an oven or by special apparatus, to make the body of the mold comparatively hard and firm. This method is used for the more intricate castings or when a fine surface is desired. The dry condition of these molds permits a higher degree of surface finishing, and, owing to the absence of moisture, but little gas is generated, and this finds easy exit through the dry sand.

Loam Molding. — When castings are made in molds that are composed of brickwork and loam, the process is termed *loam molding.* The loam used for the inner surface or face of the mold is a natural mixture of loam and clay, and the brickwork forming the outer support is laid up in courses to conform approximately to the shape required for the mold. Loam molds can be made by the use of spindle and sweep, strickle, or pattern; many loam molds require the use of all three means. Cylindrical molds are usually formed by spindle and sweep, while patterns are used to form branches, hubs, etc., that are fitted to the outside. This is the most expensive method of molding, but in many cases the cost of a large portion of the pattern work is eliminated, and for many jobs it is the most economical.

MOLDING MACHINES. Molding machines are extensively used in modern foundries, especially where duplicate castings are required in large numbers. The function of these machines varies with different types. Some molding machines are designed for ramming or packing the sand in the molds, whereas other types are intended primarily for turning or rolling over the flask or mold, and withdrawing the pattern after ramming. Molding machines were designed originally for withdrawing the pattern from the sand by a steady mechanical action, in order to avoid breaking away parts of the mold, which often occurs when a pattern is removed by hand. Withdrawing the pattern is still the most important function of certain types of molding machines, but many of the designs now in use are also arranged for ramming or packing the sand by mechanical means. There are three

general classes of molding machines: (1) Those that withdraw the pattern after the mold has been rammed by hand; (2) those that ram or pack the sand into the mold, but are not designed to withdraw the pattern; and (3) those that serve both to ram or pack the sand and withdraw the pattern from the mold. These three classes include many designs and types that differ in regard to the source of power for operating them and the mechanical action either for packing the sand or for withdrawing the pattern. For instance, some machines, especially those used for small work, are manually operated, whereas others are actuated either partially or entirely by power. There are several methods of packing or ramming sand around patterns in molds. The terms applied to the different methods indicate the general nature of the ramming operation; thus, there is the " jarring " or " jolting " method, the " squeezing " or " pressing " method, the " gravity " method, and the " roller " method.

MOLDING MACHINES, GEAR. There are two general methods of making cast gears. One is to use a pattern which is a duplicate of the gear required, and the other is to form a mold by using a special machine designed for this purpose. Patterns are liable to warp and twist out of shape and it is difficult for a patternmaker to make all of the teeth uniform in size, shape, and pitch. These patterns are also expensive to construct. When a molding machine of the ordinary type is used, the molding is done either by a single tooth or a segment containing two or three teeth. This segment is located at the required radial position and the impressions or teeth are formed in the side of the mold progressively, by indexing either the arm which carries the tooth segments or the mold itself.

Floor Type of Gear Molding Machine. — There are two general classes of machines for molding gears which are known as the *floor* and *table* types, respectively. The floor type has a vertical column carrying a horizontal slide to the end of which a vertical arm is attached. A hard-wood gear-tooth segment is attached to the end of this vertical arm which is adjusted to the required radius by the horizontal slide. The tooth impressions in the mold are rammed up one or two at a time, and the segment block is indexed around the mold in accordance with the circular pitch of the gear teeth, by means of an indexing mechanism forming part of the machine. Some machines of this type have a worm-wheel and worm which are rotated through change-gears selected to give the required indexing movement. Another method of indexing is by means of a cylindrical drum attached to the top of the vertical column and provided with annular rows of accurately-spaced holes which vary in number. In order to control the indexing movement, these holes are engaged by a plunger carried by an arm that is connected with the horizontal arm of the machine.

Table Type of Gear Molding Machine. — With the table type of gear molding machine, the flask for the mold is mounted upon a table which is given the necessary indexing movement. One design is quite similar in appearance to a large vertical boring mill. There is a circular table upon which the mold is mounted and two housings which support a cross-rail. This cross-rail carries a vertical slide to the lower end of which a one-tooth pattern block is attached. This pattern block is made of hard wood, and, when molding a gear, no draft whatever is required, because the block is removed from the mold horizontally. The table of the machine is equipped with an indexing mechanism of the change-gear and worm-wheel type. While these molding machines produce very accurate gear molds, the finished cast gear is liable to be somewhat out of round, owing to uneven shrinkage of the arms. These defects, however, may be so slight as not to affect the use of the gears for many purposes, but, when greater accuracy is desired, the rim is cast separately and is fastened to a gear center or spider. These machine-molded gears can be strengthened, if necessary, by shrouding the teeth, and they possess considerable surface hardness due to the quick cooling of the casting in the mold. Very large cast gears are produced in this way and give good results for many purposes, especially when the peripheral speeds are low and a slight amount of backlash is not objectionable. When molding a spur gear on this machine, the ring of sand inside of the cast-iron flask is first formed by means of a sweep. It is also necessary to provide a core-box for forming the arms of the gear. Geared-tooth molding machines have been applied to the molding of spur gears, bevel gears, helical gears, and worm gears.

MOLDING SAND. Molding sands, which are used in the foundry for the making of molds for castings, are of two classes: (1) "Facing sand," which comes into actual contact with the pattern, and (2) "floor" or "black sand" which is used as a support for the facing sand, and fills up the remainder of the molding box or flask. The floor or black sand is the sand that has already been used as a facing sand. Molding sand is practically a mixture composed of silica and clay, with various proportions of lime, magnesia, iron oxide, organic matter, and water, the essential qualities being porosity, plasticity, and refractoriness. The amount of silica determines, to a large extent, the last of these qualities. The shape and size of the grains of silica and the quality of the clay bond also have an effect upon the heat-resisting qualities of the sand. The less iron, lime, and magnesia the sand contains, the better it is suited for molding purposes, because these substances combined with the silica form the more or less fusible slags called "silicates." The higher the melting point of the metal to be cast, the more refractory should be the sand from which the molds are made. A very

refractory sand is required for nickel, which melts at a temperature of 2650 degrees F., and also for steel, which fuses at about the same heat. There are few natural sands that will withstand a temperature of 2500 degrees F. without fusing; therefore, in casting steel, the molds are invariably faced with a very refractory facing of pure silica bonded with fireclay, as ordinary molding sand would produce a pitted surface on the casting.

MOLDS, METAL. Metal "long-life" or permanent molds, for casting molten metal of comparatively high melting temperature, are designed so that a mold may be used continuously, replacing sand molds which are destroyed after being used once. More than 40,000 castings have been made from a single metal mold. Iron, unless of very high silicon content, if poured into a chilled mold, will be hard and white, but a process developed for casting iron in metal molds provides a heat barrier between the mold and the casting. The mold is thinly covered with a coating which checks the heat flow sufficiently to prevent the formation of chilled iron. This coating is further protected by a thick coating of lampblack, and the carbon, uniting with the skin of the casting, lowers its melting point, and thereby retards the cooling rate of the casting. This process of molding is applicable to the largest as well as to the smallest type of casting. Aluminum and brass have also been poured in these molds. See Casting in Permanent Molds.

MOLDS, PLASTER. See Plaster Molds.

MOLDS, WATER-COOLED. In brass foundries, cast-iron chilled molds have long been used for casting the plates used in producing sheet brass by the rolling process. In many foundries, especially in Europe, chilled molds of the water-cooled type are being used. A relatively thin metal wall is in contact with the molten metal on one side and with cooling water on the other. Such molds may be used continuously, castings being made every five or ten minutes, whereas with the older cast-iron chill type a comparatively large stock of molds is required to allow sufficient time for cooling before making another casting. With the water-cooled mold the rate of cooling may be varied by regulating the water supply. These water-cooled molds have proved very durable and the plates cast in them are said to be improved in their physical structure and less liable to impair the quality of the rolled sheets as the result of surface cracks and blistering of the castings.

MOLECULAR WEIGHT. The smallest mass of a chemical combination which can be conceived of as existing and yet preserving its chemical properties is known as a *molecule.* The molecular weight of a chemical compound is equal to the sum of the atomic weights of the atoms contained in the molecule, and are calculated from the atomic weights, when the symbol of the compound is known. The atomic weight of silver is 107.88; of nitrogen,

14.01; and of oxygen, 16; hence, the molecular weight of silver-nitrate, the chemical formula of which is $AgNO_3$, equals $107.88 + 14.01 + (3 \times 16) = 169.89$.

MOLTEN-METAL EXPLOSIONS. Accidents which occur in foundries are often due mainly to the handling of molten metal. With proper precautions, a number of these accidents could be reduced. Molten metal will produce serious explosions when it comes in contact with damp ground, or with any cold, damp surface. Ladles should be free from moisture before metal is poured into them, and molds should be dry. Ladles should always be heated before pouring metal into them. In foundries making small castings, double-handled ladles holding about 100 pounds of metal, or single-handled ladles holding from 25 to 40 pounds, are employed. The greatest number of accidents due to burns, in proportion to the number of men employed, occur in foundries where hand ladles are used. Many are caused by the metal splashing from the ladles as it is poured from the cupola spout. Dangers of this kind may be eliminated by placing the hand ladle inside of a larger stationary ladle, located so that it will catch the splash. A stand may also be used on which the handle ladle rests while the metal is poured, so that the workmen may step back, out of range of the splash.

MOLYBDENUM. Molybdenum is one of the metallic chemical elements, the symbol of which is Mo, and the atomic weight, 96. The metal is related to chromium, tungsten, and uranium, and is obtained in the form of a powder of gray color. Pure molybdenum, in its powder form, has a specific gravity of 9.01. It is malleable, but of great hardness, although not so hard as glass. Molybdenum is found in nature chiefly in the mineral molybdenite, and is also present in many iron ores. The United States has some of the largest molybdenum deposits in the world. It is used principally in making alloy steels. It is also employed in the manufacture of chemical reagents, dyes, glazes and disinfectants.

MOLYBDENUM STEEL. Molybdenum steels have properties similar to tungsten steels, except that a smaller quantity of molybdenum than of tungsten is required to secure the same results; hence, the main use of molybdenum is in the manufacture of high-speed steel. Molybdenum increases the elongation of steel considerably; hence, it is also used in steel which is to be manufactured into wire, because the increase of elongation necessary for wire drawing can be obtained at a comparatively small cost. A molybdenum steel for structural purposes is also made by adding a molybdenum-nickel alloy to steel. This alloy contains about 75 per cent of molybdenum and 25 per cent of nickel, or about 50 per cent of molybdenum and 50 per cent of nickel. Besides these constituents, the alloy contains small percentages of iron, carbon, and silicon, usually from 2 to 2.5 per cent of iron,

from 1 to 1.5 per cent of carbon, and from 0.25 to 0.50 per cent of silicon. The molybdenum steel made by an addition of these alloys is adapted for large crankshafts and propeller shafts, for large guns, rifle barrels, and boiler plates.

The S.A.E. molybdenum steels have carbon ranging from 0.25 to 0.55, manganese ranging from 0.40 to 0.70, chromium ranging from 0.50 to 1.10, and molybdenum ranging from 0.15 to 0.30. The composition of S.A.E. steel No. 4130 is as follows: Carbon, 0.25–0.35; manganese, 0.40–0.70; phosphorus, maximum, 0.04; sulphur, maximum, 0.045; chromium, 0.50–0.80; molybdenum, 0.15–0.25. Steel No. 4615 has carbon, 0.10–0.20; manganese, 0.30–0.60; phosphorus, maximum, 0.04; sulphur, maximum, 0.045; nickel, 1.50–2.00; molybdenum, 0.20–0.30.

MOMENT OF A FORCE. The action of a force upon a lever causes a tendency on the part of the lever to turn about its fulcrum. The magnitude of this tendency depends, first, upon the magnitude of the force acting, and, second, upon the perpendicular distance from the line of action of the force to the fulcrum. If the force is increased, or its perpendicular distance from the fulcrum is made greater, the tendency to turn the lever about its fulcrum will increase. This rotating effect of a force about a fulcrum is termed the "moment of the force" and is equal to the product obtained by multiplying the force by the perpendicular distance from the fulcrum. If the force is measured in pounds and the distance in feet, the moment is measured in foot-pounds or preferably as pound-feet (see Pound-foot), if the force is measured in pounds and the distance in inches, the moment is measured in inch-pounds or pound-inches. The most important principle to be observed with regard to moments is that the distance from the fulcrum to the force, generally called the "lever arm," must be measured on a line at right angles to the direction of the force.

MOMENT OF INERTIA. The moment of inertia of a body, with respect to an axis, is the sum of the products obtained by multiplying the weights of each elementary particle by the square of its distance from the axis; hence, the moment of inertia of the same body varies according to the position of the axis. It has its minimum value when the axis passes through the center of gravity. The moment of inertia is numerically equal to the weight of a body which, if it could be conceived of as concentrated at a distance of unity from the axis of rotation, would, if actuated by the same forces, rotate with the same angular velocity as that of the actual body. In other words, the moment of inertia bears the same relation to angular acceleration as weight does to linear acceleration. When the term "moment of inertia" is used in regard to areas, it is equal to the sum of the products obtained by multiplying each elementary area by the square of its distance

from the axis. The moments of inertia of surfaces are especially useful in calculating the strength of beams.

MOMENTUM. The momentum of a moving body is the intensity of that constant force which, resisting its movement, would bring it to rest in one second; hence, the momentum is equal to the mass multiplied by the velocity in feet per second, or:

$$\text{Momentum} = \frac{\text{weight}}{32.16} \times \text{velocity in feet per second.}$$

MOMME. This is a Japanese measure of weight, equal to 3.75 grams or 57.86 grains. One momme is divided into 10 funs.

MONEL METAL. The alloy known as *monel metal*, consists of copper and nickel, but is not made by melting these two constituents and mixing them together; instead, monel metal is a so-called "natural" alloy, made from an ore containing copper and nickel, no attempt having been made to separate the two metals. Monel metal has the strength of steel, shines like silver, and is less corrodible than bronze. One important use of this material is for ship propellers. The composition of monel metal varies somewhat. It contains usually from 24 to 28 per cent of copper, from 67 to 74 per cent of nickel, and from 0.5 to 5.25 per cent of iron. The melting point of monel metal is 1360 degrees C. (2480 degrees F.). Its tensile strength is about 70,000 pounds per square inch, with an elongation in two inches of 30 per cent for cast metal; and a tensile strength up to 85,000 pounds per square inch, with an elongation in two inches of 40 per cent for rolled metal. The compressive strength of monel metal is about 19,000 pounds per square inch, and its shearing stress about 31,800 pounds per square inch. Its weight is about 0.32 pound per cubic inch; 543 pounds per cubic foot. Its specific gravity is about 8.87. Monel metal may be forged by heating it to a temperature of from 600 to 900 degrees C. (about from 1100 to 1650 degrees F.). Monel metal acts somewhat like steel when it is made into castings, and, hence, many of the same rules are applied.

MONITOR LATHES. Turret lathes which are intended principally for brass work are often referred to as *monitor lathes*, the name "monitor" in this connection indicating a revolving turret. This name is not applied to the same design of turret lathe by different manufacturers, although, in general, it indicates a comparatively small turret lathe which, in many cases, is provided with a thread-chasing attachment of the Fox lathe type and is designed principally for turning, boring, and threading parts made of brass. Some lathes which are listed as the monitor type have a stock-feeding mechanism, whereas others do not have this feature. The turret may or may not have power feed, and some monitor lathes have a cross-feed for the

turret, whereas others only have the longitudinal feeding movement. The thread-chasing attachment is one of the important features of the monitor or Fox lathe, as it enables parts to be threaded rapidly, and is used on many classes of work in preference to a die held in the turret.

MONOVALENT. Monovalent, also known as univalent, is a term used to designate that an atom of an element (like hydrogen) combines with but one atom of another element.

MOORE & BEEMAN RULE. This is a rule employed for finding the board measure of logs, as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet. Usually the diameter is measured inside of the bark at the small end.

MORSE TAPER. Dimensions relating to Morse standard taper shanks and sockets may be found in tabular form in engineering handbooks. The taper for different numbers of Morse tapers is slightly different, but is approximately $\frac{5}{8}$ inch per foot, the exact figures being as follows: No. 0 taper, 0.625 inch per foot; No. 1, 0.600; Nos. 2 and 3, 0.602; No. 4, 0.623; No. 5, 0.630; No. 6, 0.626; No. 7, 0.625. Morse taper shanks are used on a variety of tools, and are used exclusively on twist drills.

MORTISE-AND-TENON. The joining of two pieces of wood by what is termed a mortise-and-tenon joint is effected by first cutting a rectangular hole or slot (called the mortise) in one member. The end of the other member is then cut to form the tenon which fits into the mortise. The mortise-and-tenon joint may be either "through" or "blind." If through, the tenon fits a mortise cut completely through the first member; if blind, the tenon fits a mortise cut part way through. In joining two pieces of equal thicknesses, with this type of joint, the mortise-and-tenon are generally cut symmetrically so that when the two members are put together their sides will be in the same plane.

MOTOR CONVERTERS. The motor converter is only used for converting from alternating current to direct current. It consists of an ordinary induction motor with phase-wound rotor, and a direct-current generator. The revolving parts of both machines are mounted on the same shaft and the rotor of the motor and the armature of the direct-current machines are also electrically connected.

MOTOR-GENERATOR SETS. A motor-generator is defined in the American Institute of Electrical Engineers' standardizing rules as a transforming device consisting of a motor mechanically coupled to one or more generators. For convenience, motor-generator sets may be divided into

three general classes, as follows: (1) Direct current to direct current, including boosters, balancers, and dynamotors. (2) Alternating current to direct current, or vice versa, including light, power, and railway service, and flywheel equalizing sets. (3) Alternating current to alternating current, as in the case of frequency changers.

MOTOR HISTORY. The origin of the electric motor may be traced back to the experiments of Faraday in 1821. These experiments were followed by crude forms of magnetic apparatus which had moving elements. In 1826, 1830 and 1831 crude magnetic devices containing moving elements were made, and in 1832 and 1834 rotary motors were constructed which had electromagnets both in the field and armature. All of these primitive designs were operated by batteries and the practical development of the motor did not begin until the dynamo was invented. The structural relationship between the dynamo and motor was discovered accidentally in 1873, due to the fact that one dynamo was inadvertently connected to another in active operation. When it was found that the dynamo revolved as the result of this connection to the other machine, the subsequent development and wide application of the electric motor was assured. This discovery was made at an industrial exhibition in Vienna.

MOTORS, ALTERNATING-CURRENT. Electric motors for use on alternating-current circuits may be divided into three groups — induction, synchronous, and commutator. The induction motor is much more extensively used than the others. See Induction Motors; Synchronous Motors; and Commutator Motors.

MOTORS, DIRECT-CURRENT. A direct-current motor transforms electrical energy into mechanical energy and the supply current is practically a non-pulsating direct current of electricity. There are two main parts which form an electric motor; one is known as the *field*, the other as the *armature*. The primary object of the field is to supply a body of magnetism at definite points on the periphery of the armature, in complete magnetic circuits interlinking the armature windings. These magnetic circuits are of definite polarity and fixed in space. The function of the armature is to receive current from the source of power and to distribute that current through its windings which lie along its periphery. These windings cut successively the stationary magnetic circuits set up by the field. The passage of the current in the armature windings through these magnetic circuits sets up a reaction under each pole. This produces a force of repulsion in the windings which causes the armature to revolve and results in mechanical power. If all the currents flowing in the windings under a single pole of the field of magnetism are added together, what might be termed a " sheet " of current would be obtained. The torque or turning moment is created by

the reaction on the field of these sheets of current while flowing through the armature windings. With this reaction, which creates mechanical power, there is set up an electrical reaction. This appears as a voltage in opposition to the flow of current through the windings. It is a counter-pressure to the direction of the impressed voltage of line pressure and is called *counter-electromotive force.* It is a property of the utmost importance, as it enables a shunt motor to be self-governing.

MOTORS, SELECTION. In selecting the electrical equipment for a manufacturing plant, a system using alternating-current motors on all constant-speed machines, with direct current for the remainder, is probably the best. The second choice is direct current, because any machine tool can be successfully driven by this type of motor. The squirrel-cage and wound-rotor alternating-current motors are the two forms generally used. The squirrel-cage motor is practically a constant-speed machine, and should be used for driving machine tools producing a constant load. The wound-rotor motor is capable of exerting greater starting torque with less current than the squirrel-cage type.

Direct-current Motors. — The three types of direct-current motors generally used are the shunt, compound, and series. The series motor is not employed as extensively as in the past. Because the compound-wound motor does not attain as high light-load speeds, it is preferable for general use. The shunt-wound direct-current motor is essentially a constant-speed machine, the slip or reduction in speed from no load to full load being about 5 per cent for the average motor. This factor is inherent in any motor, whether of the alternating- or direct-current type. The speed of any direct-current motor is governed by the rate at which the armature conductors pass through the flux set up by the field magnets. This rate is a product of armature conductors per unit time and flux, and is constant, under definite conditions, in any particular motor. Therefore, in a motor where the field strength is constant, the speed will be constant, and the current will increase rapidly if the load tends to lower this speed.

When the field strength is varied, as for the shunt-wound adjustable-speed motor, a speed variation is obtained, because to maintain the particular " product " or " rate " with a varying field strength, will require a change in the number of armature conductors passing through the flux, per unit time. It is obvious that the armature speed must change to accomplish this. The squirrel-cage induction motor is comparable to the shunt-wound, constant-speed, direct-current motor.

Variable-speed and Adjustable-speed Motors. — Variable speed must not be confused with adjustable speed. So-called " variable " speed is obtained (usually with a constant-speed motor) by introducing resistance in the arma-

ture circuit. The reduced speeds obtained by this method will vary with each change of load. This is not an economical scheme, because a certain part of the power taken from the line is wasted in heat generated in the resistor. This loss is dependent on the speed reduction, being equal to the output of the motor, when the speed is reduced to one-half. Besides the energy loss in the resistor, the motor output is reduced. The adjustable-speed motor uses a resistor in the shunt field circuit, and while there is a loss in this resistor, it is negligible, because the total energy input to the field is only about 3 to 4 per cent of the input to the motor; furthermore, since the field current is reduced at the higher speeds, this loss is decreased. The horsepower output of an adjustable-speed motor is constant in that the rating at high and low speeds is the same.

Compound-wound Motors. — Compound-wound motors, which have a part of the field energized by the armature current, slow down under overloads, and speed up with light loads, due to the varying field strength. This produces a motor with a higher slip than the shunt machine, which is an advantage for certain drives. The average compound-wound motor has fields of which 80 per cent is shunt, and 20 per cent series. This means that with full load there is full field, while with 25 per cent overload, the series portion becomes 0.20×1.25, or 25 per cent. This, added to the 80 per cent part, which is constant, makes a total of 105 per cent, causing a speed reduction.

Series Motors. — In the series motor, all the field is produced by armature current. It is obvious that with a very light load there is practically no field, and the armature will run at a very high speed to maintain the "product" or "rate" referred to above. Also, with a 25 per cent overload, the field will have a strength of 125 per cent instead of 105 per cent as for the compound machine, and a lower speed will result. Commercial series motors do not produce the same speeds or torques on overload that a theoretical motor would, because the iron used in the fields becomes saturated after a certain flux is produced, and any current in excess of that which will saturate the fields has practically no effect on the field strength. Because of this condition, it has been found more desirable to use a motor with 50 per cent shunt and 50 per cent series on many of the machines heretofore driven by a series motor. The "50-50" motor will produce nearly the same torque per ampere, and has the advantage of a lower no-load speed. Approximately 150 per cent full load speed is obtained on light load.

MOTOR SPEED CLASSIFICATION. Electric motors may, for convenience, be classified with reference to their speed characteristics as follows: (1) Constant-speed motors, the speed of which is either constant or does not vary materially; such as synchronous motors, induction motors with small

slip, and ordinary direct-current shunt motors. (2) Multi-speed motors (two-speed, three-speed, etc.), which can be operated at any one of several distinct speeds, these speeds being practically independent of the load, such as motors with two armature windings, or induction motors in which the number of poles is changed by external means. (3) Adjustable-speed motors, in which the speed can be varied gradually over a considerable range, but when once adjusted remains practically unaffected by the load, such as shunt motors designed for a considerable range of speed variation. (4) Varying-speed motors, or motors in which the speed varies with the load, ordinarily decreasing when the load increases, such as series motors, compound-wound motors, and series-shunt motors. As a sub-class of varying-speed motors may be cited adjustable varying-speed motors, or motors in which the speed can be varied over a considerable range at any given load, but, when once adjusted, varies with the load, such as compound-wound motors arranged for adjustment of speed by varying the strength of the shunt field.

MOTOR SPEED REGULATION. Speed regulation of shunt-wound and compound-wound motors may be effected by inserting resistance in the armature circuit of the motor, or by inserting resistance in the shunt-field circuit. The first method reduces the speed of the motor below its normal rated speed. The second method increases the speed of the motor above normal. By a combination of the two methods, the speed of a motor may be both decreased below and increased above normal speed, thus affording a wide range of speed variation.

Speed regulation by armature resistance is open to two objections: (1) The difficulty of maintaining constant speed under varying load conditions. (2) The necessity of wasting energy to secure speed reductions. For the first reason it cannot be applied to a service requiring a constant speed independent of the load, such as machine tool drives. In regard to the comparative costs of the two systems, it may be said, in general, that field control is preferable where the motor operates for long intervals at speeds between 50 and 100 per cent of maximum speed. If the motor operates for long intervals at speeds between 75 and 100 per cent, and only occasionally at speeds below 75 per cent, the combination control gives the best results. In cases where the equipment is operating for long periods at maximum speed, and only occasionally at lower speeds, the armature control shows the best economy.

Series Motors. — The speed of series motors is controlled by inserting resistance in series with the armature and consequently also with the field. Where two or four motors are used, as with railway equipments, the motors are also connected in series; for example, with a two-motor equipment, the

sequence of the speed control is as follows: On the first point of the controller, the two motors are in series with all the resistance; then the resistance is successively cut out, which will give a speed of about one-half the full speed. On the next step, the two motors are connected in parallel, and half of the resistance is connected in series with each motor, and finally the resistance is again successively cut out, until the motors are subjected to the full-line voltage which corresponds to the full speed.

Alternating-current Motors. — Speed regulation by rheostatic control is accomplished by inserting an adjustable resistance in the secondary circuit. With this system, the loss in efficiency is almost in direct proportion to the reduction in speed. The multi-speed motor is provided with two or more separate windings which can be connected so as to change the polar grouping. The number of speeds to be obtained in this manner is entirely dependent upon the number of windings.

The concatenated or cascade connection requires two induction motors mounted on the same shaft, one of which at least, has a phase-wound rotor. The primary of one motor is connected to the secondary of the other, and either motor may be provided with one or more windings so as to change the number of poles. The dynamic control is used with polyphase induction motors with wound rotor, the secondary resistance being replaced by a dynamic regulating set. With the ordinary rheostat control the secondary energy is dissipated as heat and thus wasted, whereas with the dynamic regulation the major portion of this energy is returned to the system.

The speed regulating brush-shifting motor consists essentially of a stator with a three-phase distributed winding and a rotor similar to that of a standard direct-current motor, but with a larger number of brushes which can be shifted by worm-gearing through a conveniently located hand-wheel. The motor is started, accelerated, stopped, and reversed by shifting the brushes, and it will develop a torque which is proportional to the square of the line current and the angle of the brush shift. Compared with an ordinary induction motor with rheostatic control, a much better efficiency and power factor is obtained with the brush-shifting motor.

MOTOR STARTERS. Motor starters, starting rheostats, or "starting-boxes," as they are sometimes called, are used for starting an electric motor without excessive current inrush and bringing it gradually up to its normal speed. The characteristics of the motors controlled also call for different methods of control. A starting rheostat used with the ordinary shunt or compound motor cuts out steps of resistance in succession as the lever is passed over the contacts. From five to fifteen seconds is the usual period for starting a motor under ordinary load. Where the motor is driving a machine which requires very heavy starting torque, a starting rheostat

having resistance designed for a longer starting period should be selected. Speed regulators for machine tool motors, fans, pumps, printing presses, controllers for hoists, cranes, elevators, etc., are made in types for every application, each providing special features, as required. In all cases the character of the drive and the motor data must be considered.

MOTORS UNDER AUTOMATIC CONTROL. For some motor applications, it is desirable to have the starting-box automatically operated, or capable of being started by pushing a button or closing a switch at some remote point. Automatically operated control equipments are generally of the magnetic contactor type, including interlocking devices and current limiting relays. Some device, either hand or automatically operated, is used to close the main switch connecting the motor to the line, all the resistance being inserted in the secondary circuit. The current limiting relays are held open by the sudden inrush of current, and none of the secondary contactors can be energized until, at partial speed of the motor, the current falls to some predetermined value. The interlocks control the sequence at which the contactors are to close, and thus short-circuit and cut out the resistance; thus with this type of automatic control the acceleration is governed entirely by the safe value of the current, and the equipment is, therefore, protected from abuse. The master controller or control switch may be placed in any location remote from the motor and the control panel. In connection with motor-driven pumps and air compressors, the self-starter finds one of its widest fields of usefulness. By means of a switch operated by a float in the tank, the circuit to the motor is automatically opened and closed through the self-starter whenever the water in the tank reaches a predetermined high or low level. In compression tank systems, and when used with air compressors, a pressure gage is substituted for the float switch, the circuit being made and broken as the needle, or indicator, moves back and forth between two fixed points.

MOTOR TYPES. See Compound-wound Motors; Commutator Motors; Induction Motors; Series-wound Motors; Shunt-wound Motors; Synchronous Motors.

MOTTLING. Mottling is a method for obtaining a mottled coloring effect on metal parts. On steel, such colors may be obtained by heating the object to a cherry-red heat for several minutes in cyanide of potassium and then dipping it in clear water, moving it about in the bath vigorously.

MU. A Chinese surface measure, legalized in 1908, equal to 6.144 ares or 0.15 acre.

MUFF COUPLING. A muff coupling is one that is split longitudinally into two halves which are bolted together over the joint of the two shafts.

A key and keyway are provided in one half of the coupling and in the shafts, to provide a positive drive.

MUFFLE BRAZING. This is a method of brazing in which the parts to be united are enclosed in a tube or muffle, insuring uniform heating and clean, smooth surfaces. This method is especially applicable to the brazing of alloys the melting temperatures of which are nearly the same as that of the spelter solder. See also Brazing.

MUFFLE FURNACES. The principle of muffle furnaces is to improve the quality of the steel by keeping the heated work separated from the combustion gases by the use of a " muffle " or separate container into which the work is placed. There is no doubt that this is advantageous under the usual conditions of firing a furnace. However, with a properly designed furnace and proper burning of fuel, the combustion gases may be made practically harmless to the steel. The muffle type of furnace is apt to have more oxygen in contact with the metal than the open heating-chamber type as the result of sealing the work. To prevent oxidation, charcoal is often placed in the muffle to generate a protective gas that will burn up the oxygen and thus prevent the steel from scaling.

MULE PULLEYS. This term is applied to the idler pulleys used in conjunction with a right-angle belt drive which is so arranged that the belt in passing from the driving pulley to the driven pulley, must be guided or supported by idlers.

MULT-AU-MATIC. This is a trade name applied to a vertical, multiple, automatic machine tool of the station type. This machine (now built in 4- and 6-spindle models) has work-holding chucks with tool slides and tools above for performing the necessary operations progressively as the chucks and work index periodically from one station or tool position to the next. Thus the tools of each position operate simultaneously and every indexing movement brings a finished part to the first position, where it is replaced with a rough casting or forging.

MULTIPLE-CONDUCTOR CABLE. This is an electrical conductor consisting of a combination of conductors insulated from one another so as to be suitable for carrying several different electric currents.

MULTIPLE-CRANK PRESSES. Power presses having a multiple-crank drive are made in many different designs and sizes. The double crank drive is applied to most presses included in this class, although three- and four-crank presses, varying in width between the housings from 3 to 10 feet, are used quite commonly. The multiple-crank design is employed for operating large cutting, bending, stamping, and forming dies or gangs of

punches and dies extending over a large area. This kind of press is also adapted for punching holes in wide sheets, when it is not desirable to use a press having a deep-throated frame. Multiple-crank presses are used for the manufacture of sheet iron and steel goods, such as steel and wrought-iron ranges, shingles, panelled ceilings and sidings for buildings, cornice work, metal furniture, automobile parts, metal radiators, etc. The larger sizes are employed for heavy stamping, cutting, perforating, forming, and bending operations in connection with the manufacture of heavy metal parts of automobiles and other lines of work.

MULTIPLE-PLUNGER PRESS. The multiple-plunger press is designed for producing by a series of simultaneous operations a complete article at every revolution of the press. It is constructed in various styles and sizes, the number of plungers varying from 3 to 8. A design most extensively used for the general run of small work is a six-plunger machine. This press can be used for such operations as blanking, cupping, piercing, forming, embossing, stamping, curling, bending, redrawing, perforating, clipping, etc., and, in fact, almost any like operation that is performed on sheet metal. It can also be used when only three or more operations are required, by having the remaining plungers run idle. The multiple-plunger press was originated at the Waterbury Brass Co., Waterbury, Conn., in the year 1860, its inventor being Robert Cairns.

MULTI-SPEED WINDING. This type of winding consists of two or more separate windings for alternating-current motors, which can be so connected as to change the polar grouping. In this way, a number of different speeds can be obtained in the motor.

MUNTZ METAL. Muntz metal is a brass containing about 60 per cent of copper and 40 per cent of zinc. It is used in naval work for bolts and nuts not subjected to the action of salt water, and also for castings and fittings which are not subjected to salt water. The U. S. Navy specifications, for both cast and rolled Muntz metal, require a composition of from 59 to 62 per cent of copper, and from 39 to 41 per cent of zinc, with lead not exceeding 0.6 per cent. The tensile strength is 40,000 pounds per square inch, and the elongation in two inches, 25 per cent. Experiments for determining the effects of heat-treatment on Muntz metal indicate that after annealing cold-drawn bars to 500 degrees C. (about 930 degrees F.), for 48 hours, the tensile strength is about 50,000 pounds. The metal is remarkably immune from oxidation during heating. It is not advisable to anneal at a higher temperature than that mentioned.

MURIATIC ACID. Muriatic acid is an aqueous solution of hydrogen chloride, the chemical formula of which is HCl; chemically known as hydrochloric acid.

MUSCOVITE. See Mica.

MUSHET STEEL. Mushet steel is a tool steel discovered in 1868 by Robert F. Mushet. This steel is known as *self-hardening*, and also as *air-hardening*, steel. Mushet steel contains a high percentage of tungsten and has the property of becoming hard, after heating, without the usual quenching. It is simply a kind of high-speed steel.

MUSIC WIRE. Music or piano wire is made from a high grade of steel in diameters of from 0.004 to 0.180 inch. There are many different gages to which this class of wire is made, but the piano wire gage designated as the "American Steel & Wire Co.'s Music Wire Gage" is adopted as standard for piano wire in the United States, upon the recommendation of the U. S. Bureau of Standards. The smaller diameters of music wire have an ultimate tensile strength of from 300,000 to 340,000 pounds per square inch. The composition of this wire is as follows: Carbon, 0.57 per cent; silicon, 0.09 per cent; sulphur, 0.011 per cent; phosphorus, 0.018 per cent; manganese, 0.425 per cent.

MYCALEX. "Mycalex," a composition of ground mica and lead borate, is an insulating material used for radio high-frequency insulators. It has better insulating properties than porcelain, is light gray in color and has a metallic ring. It is used in the manufacture of bases for radio transmitter tubes, for aerial insulators in high frequency work, and for numerous similar applications.

NAIL-HOLDING QUALITIES OF WOODS. Tests made to determine the nail-holding qualities of various woods, with various sizes of nails from 8d to 60d, indicate that white pine has a very low holding resistance as compared with yellow pine, white oak, chestnut, and laurel. As a general average, if the holding resistance of wire nails in white oak is assumed to be 100 per cent, then the holding resistance of wire nails in white pine is 18 per cent; in yellow pine, 34 per cent; and in laurel, 69 per cent. The holding resistance of cut nails, compared with wire nails in white oak as 100 per cent, is as follows: Cut nails, in white pine, 43 per cent; in yellow pine, 71 per cent; in white oak, 130 per cent; in chestnut, 73 per cent; and in laurel, 128 per cent. Experiments relating to the holding resistance of 6d nails in different kinds of woods, compared with the holding resistance in white oak as 100 per cent, gave the following results: White pine, 31 per cent; yellow pine, 54 per cent; bass wood, 40 per cent; hemlock, 61 per cent. In some kinds of wood, the holding resistance of cut nails is twice that of wire nails. This is especially the case in the softer woods. In the harder woods, the superiority of the cut nail over the wire nail varies from 30 to 50 per cent. In white pine, cut nails driven with the taper across the grain show a superiority over wire nails of as high as 135 per cent.

Spike-gripping Power. — Experiments show that generally twice as much force is required to extract spikes from oak as from white or yellow pine. The spikes in the experiments mentioned were driven across the grain of the wood. When driven with the grain, the holding power is reduced at least one-half. The condition of the wood affects the gripping power. For instance, experiments have shown that the force required to draw spikes $\frac{9}{16}$ by $\frac{9}{16}$ inch, driven $4\frac{1}{4}$ inches into seasoned oak, is about 4280 pounds. The same spikes driven into unseasoned oak require 6500 pounds to draw.

NAPHTHA. The following kinds of naphtha are most commonly used: Coal-tar naphtha, which is a volatile oil obtained by the distillation of coal-tar; petroleum naphtha, an oil consisting of the more volatile hydrocarbons distillated from petroleum; shale naphtha, an oil obtained by distillation of bituminous shale; and bone naphtha, also known as *bone oil* or *Dippel's oil*, obtained in the carbonization of bones for the manufacture of animal charcoal. Naphtha oils are used for many purposes in the industries, and to some extent in so-called naphtha engines, in small yachts and launches. The naphtha is vaporized in a boiler and the vapor is used in the engine cylinder the same as steam, the action being that of expansion, due to vaporization. The naphtha engine, therefore, is not an internal-combustion engine. The vapor, after having been used in the cylinder, is condensed and returned to the boiler. A portion of the naphtha vapor is used for fuel

under the boiler. The chief advantages of the naphtha engine and boiler for launches have been claimed to be the saving of weight and the rapidity of operation as compared with the steam engine. At the present time, these engines have been replaced largely by internal-combustion engines.

NAPIER FORMULA. The Napier formula for the discharge of saturated steam was proposed by S. D. Napier, an English engineer, as a result of carefully conducted experiments, made by him to test the accuracy of abstruse mathematical formulas of flow that had previously been relied upon, which formulas he found to be in error. Napier's tests indicated that the more intricate formulas modified to the simple formula, $W = (P \times A) \div 70$, would be nearly true in all cases where the initial pressure is $1\frac{2}{3}$ times the pressure of the gaseous medium into which steam may be discharged, and the formula has been extensively verified and is accepted as substantially correct for such conditions. In the formula, W is the number of pounds of steam discharged per second from an aperture; P is absolute pressure (absolute pressure is taken, because the physical properties of steam depend upon absolute pressure and not upon gage pressure, which is accidental and depends on the variable pressure of the atmosphere); A is the area in square inches of the aperture.

NAPIERIAN LOGARITHMS. The *Napierian* or *hyperbolic* logarithms differ from the common logarithms in that the base of the hyperbolic logarithms is 2.71828, whereas the base of the common logarithms is 10. The name "Napierian" logarithms is derived from the inventor of this mathematical time-saver, John Napier, a Scotchman, born in 1550. The work in which the logarithms were first described appeared in 1614.

NAPIER MOTION. When a gear or pinion is in mesh with a single rack and rotates in one position, obviously both the gear and rack must reverse their direction of motion at the end of each stroke if a reciprocating motion is to be imparted to the driven member to which the rack is attached. The gear, however, may rotate continuously in one direction if it is arranged to engage the upper and lower sides of a rack designed especially to permit such engagement. A mechanism of this type, known as the Napier motion and also as "mangle gearing," has been used for imparting a rectilinear motion to the tables of flat-bed printing presses.

NATIONAL STANDARD SCREW THREADS. See American Standard Screw Threads.

NATIONAL WIRE GAGE. See Steel Wire Gage.

NATIVE COPPER. Native copper, also known as malleable copper and virgin copper, is practically pure natural copper, having all the properties

of refined metal. It is mined extensively in the Lake Superior district, and in Bolivia.

NATURAL ALLOY STEEL. Natural alloy steel is so designated because of the fact that this class of steel is manufactured from an ore in which nickel and chromium are alloyed by nature. About 1900, this ore was discovered at Mayari and Moa in the Province of Oriente, in the eastern part of Cuba. These ores show a remarkable uniformity of composition and cover some 25,000 acres. The various grades of steel into which this ore is manufactured contain from 1.00 to 1.50 per cent of nickel; from 0.20 to 0.70 per cent of chromium; from 0.15 to 1.50 per cent of carbon; and from 0.50 to 0.80 per cent of manganese; the silicon is kept below 0.20 per cent, and the phosphorus and sulphur, below 0.04 per cent. These two latter elements, however, seldom reach 0.035 per cent, and a phosphorus content that is below 0.02 per cent is often obtained. These natural alloy steels are made by the open-hearth process and are, in the heat-treated condition, equal to $3\frac{1}{2}$ per cent nickel steel. In some ways, they are superior to this steel and especially is this true of the grade that contains the higher percentages of chromium, or when they are manufactured into parts that have a comparatively large sectional area. They are also cheaper than the nickel steels made by the same process. Natural alloy steel can be hammered, rolled, drop-forged, pressed, stamped, or machined with the same ease and at the same temperatures as carbon steel; no special precautions are necessary. Natural alloy steels are largely used in the manufacture of automobile parts. One grade containing as low as 0.15 per cent of carbon is used for case-hardened parts. Speed change-gears, differential gears, etc., are made from steel containing 0.20 per cent of carbon. The grades containing high percentages of carbon are used for spindles, rear axles, crankshafts, and transmission gears. Natural alloy steels, like all other steels, will attain the highest strength only when properly heat-treated. In the untreated or annealed state, they show a tensile strength and elastic limit that is from 8000 to 10,000 pounds per square inch higher than carbon steels of the same carbon content, but, when properly heat-treated, they compare favorably with other alloy steels.

NATURAL CEMENT. This cement is made by burning mixtures of clay and carbonate of lime, or by calcination of a silicious limestone containing magnesia, and may be considered as Portland cement of inferior quality. Natural cement is a good building material for ordinary purposes, but is not as suitable for heavy and important concrete constructions as Portland cement. Natural cement does not develop its strength as quickly and is not as uniform in composition as Portland cement. It is satisfactory to use, however, in massive masonry, where weight rather than strength is the essential feature.

NAUTICAL MEASURE. 1 league = 3 nautical miles; 1 nautical mile (often called "knot") = 6080.2 feet = 1.1516 statute mile; one degree at the equator = 60 nautical miles = 69.096 statute miles; 360 degrees = 21,600 nautical miles = 24,874.5 statute miles = circumference of earth at the equator.

NAVAL BRONZE. This is an alloy containing, according to the U. S. Navy specifications, from 59 to 63 per cent of copper, from 0.5 to 1.5 per cent of tin, with the remainder zinc, and not more than 0.2 per cent of lead and 0.06 per cent of iron. It is used for rolled rods, principally for propeller blade bolts, condenser bolts, pump rods, and, in general, for parts requiring strength and non-corrosive properties.

Naval brass or Tobin bronze contains, according to S.A.E. specification No. 76 for naval brass tubing, the following composition in percentages: Copper, 59.00 to 62.00; tin, 0.50 to 1.50; iron, maximum, 0.10; lead, maximum, 0.30; other impurities, maximum, 0.10; zinc, remainder.

NAXOS EMERY. This is an abrasive obtained from Naxos, an island in the Ægean Sea. It is considered the best natural emery obtainable, containing about 63 per cent of crystalline alumina, which is the cutting material.

NEEDLE VALVE. A needle valve is provided with a long tapering point in place of the ordinary valve disk. The tapering point permits fine gradation of the opening. At times called a *needle point valve.*

NEGATIVE NUMBERS. The ordinary numbers may also be considered positive and negative in the same way as the graduations on a thermometer scale. When we count 1, 2, 3, etc., we refer to the numbers that are larger than 0 (corresponding to the degrees *above* the zero point), and these numbers are called positive numbers. We can conceive, however, of numbers extending in the other direction of 0; numbers that are, in fact, less than 0 (corresponding to the degrees below the zero point on the thermometer scale). As these numbers must be expressed by the same figures as the positive numbers, they are designated by a minus sign placed before them. For example, -3 means a number that is as much less than, or beyond, 0 in the negative direction as 3 (or, as it might be written, $+3$) is larger than 0 in the positive direction.

A negative value should always be enclosed within a parenthesis whenever it is written in line with other numbers; for example:

$$17 + (-13) - 3 \times (-0.76).$$

In this example (-13) and (-0.76) are negative numbers, and, by enclosing the whole number, minus sign and all, in a parenthesis, it is shown that the minus sign is part of the number itself, indicating its negative value.

It must be understood that in the expression $7 - 4$, the value 4 is not a negative number, although it is preceded by a minus sign. In this case the minus sign is simply the sign of subtraction, indicating that 4 is to be subtracted from 7; but 4 is still a positive number or a number that is larger than 0.

Negative numbers are most commonly met with in the use of logarithms and natural trigonometric functions. The following rules govern calculations with negative numbers.

1. *A negative number can be added to a positive number by subtracting its numerical value from the positive number.*

$$4 + (-3) = 4 - 3 = 1.$$
$$a + (-b) = a - b.$$

2. *A negative number can be subtracted from a positive number by adding its numerical value to the positive number.*

$$4 - (-3) = 4 + 3 = 7.$$
$$a - (-b) = a + b.$$

3. *A negative number can be added to a negative number by adding the numerical values and making the sum negative.*

$$(-4) + (-3) = -7.$$
$$(-a) + (-b) = -(a + b).$$

4. *A negative number can be subtracted from a negative number by subtracting the numerical values and making the difference negative.*

$$(-4) - (-3) = -1.$$
$$(-a) - (-b) = -(a - b).$$

If, in a subtraction, the number to be subtracted is larger than the number from which it is to be subtracted, the calculation can be carried out by subtracting the smaller number from the larger, and indicating that the remainder is negative.

$$3 - 5 = -(5 - 3) = -2.$$
$$(a - b) = -(b - a).$$

5. *When a positive number is to be multiplied or divided by a negative number, multiply or divide the numerical values as usual; the product or quotient, respectively, is negative.* The same rule is true if a negative number is multiplied or divided by a positive number.

$$4 \times (-3) = -12. \qquad (-4) \times 3 = -12.$$
$$15 \div (-3) = -5. \qquad (-15) \div 3 = -5.$$
$$a \times (-b) = -ab. \qquad (-a) \times b = -ab.$$
$$\frac{a}{-b} = -\frac{a}{b}. \qquad \frac{-a}{b} = -\frac{a}{b}.$$

6. *When two negative numbers are to be multiplied by each other, the product is positive. When a negative number is divided by a negative number, the quotient is positive.*

$$(-4) \times (-3) = 12. \qquad (-4) \div (-3) = 1.333.$$

$$(-a) \times (-b) = ab. \qquad \frac{-a}{-b} = \frac{a}{b}.$$

The two last rules are often expressed for memorizing as follows: " Equal signs make plus, unequal signs make minus."

NEGATIVE RAKE. This term is sometimes applied to turning or other metal-cutting tools which are so ground that the tool has less keenness than one ground to a rake angle of zero. See Rake of Metal-cutting Tools.

NEON. Neon is a gaseous chemical element, the symbol of which is Ne, and the atomic weight, 20.2. Neon occurs in very small quantities in the earth's atmosphere, and was first discovered in 1898. It is a colorless gas having a specific gravity (compared with air as unity) of 0.674. It becomes liquid at a temperature of −243 degrees C. (−405 degrees F.), and solidifies at a temperature of −253 degrees C. (−423 degrees F.). Neon occurs in the air in greater proportions than any of the other rare gases, except argon. The presence in air is to the extent of from 1 to 2 volumes in 100,000 volumes of air.

NERNST LAMP. The Nernst electric lamp, also known as the " glower " lamp, employs for its incandescent material a fine rod made of rare oxides. The oxide is generally made in the form of a paste, and then forced through a die in order to give it the required shape. The *glower* thus formed is then dried or " roasted," cut to the desired length for the lamps, and provided with platinum terminals to make contact with the circuit. The rare oxide rod or glower is nonconducting when cold, and must, in consequence, be heated before it can conduct the current and produce light. Therefore, a heater is required for the lamp, which will bring the temperature of the glower up to a point where it will become a conductor.

NEUTRAL AXIS. The neutral axis of a beam subjected to a bending stress is that line or plane in which the fiber stress equals zero. Strictly speaking, the neutral axis should be simply a line, and when considering the whole plane in which the fiber stress equals zero, it should be referred to as the *neutral plane;* but this is seldom done in engineering literature, the expression " neutral axis " being very frequently used in place of " neutral plane." If the beam is of a homogeneous material and subjected to bending stresses only, the neutral axis passes through the center of gravity of the cross-section. If the beam is subjected to combined flexure and direct

stress, then the neutral axis will not pass through the center of gravity. All engineering materials may be considered as homogeneous except beams made from reinforced concrete, in which the neutral axis will not be located at the center of gravity of the cross-sectional area.

NEUTRAL FLAME. Ordinarily in welding metals by the autogenous process, it is essential to so regulate the gases used that a neutral or non-oxidizing flame is obtained. If oxygen and acetylene are used complete combustion is effected when one volume of acetylene burns with two and one-half volumes of oxygen. According to one authority the highest flame temperature is produced by a mixture at the torch of one volume of acetylene with one volume of oxygen, the surrounding air supplying the additional one and one-half volumes of oxygen necessary to complete combustion. The flame produced from such a mixture is neutral in that it does not produce chemical changes detrimental to the metal with which it is in contact. To adjust a torch for a neutral flame, first adjust so that the flame shows a secondary or middle cone characteristic of excess acetylene; then reduce the amount of the acetylene until this secondary cone just disappears.

NEUTRAL PLANE. A neutral plane is the plane in a beam subjected to a load tending to bend it in which neither compression nor tension will occur. See Neutral Axis.

NEWTON'S LAWS OF MOTION. The first clear statement of the fundamental relations existing between force and motion was made in the seventeenth century by Sir Isaac Newton, the English mathematician and physicist. It was put in the form of three laws, which are given as originally stated by Newton: I. Every body continues in its state of rest, or uniform motion in a straight line, except in so far as it may be compelled by force to change that state; II. Change of motion is proportional to the force applied and takes place in the direction in which that force acts. III. To every action there is always an equal reaction; or, the mutual action of two bodies are always equal and oppositely directed.

NIB. The term nib is sometimes applied to the gaging end of a plug gage consisting of a handle into which the nib or gaging end is inserted. The nib may be of plain cylindrical form for gaging the diameters of holes, or it may be a threaded form for gaging screw thread sizes.

NIBBLING MACHINE. The " nibbling machine " is so named because it is used for cutting sheet metals to any desired outline, by means of a rapidly reciprocating punch which takes numerous small cuts. The punch is of small size and enters a die held in the bedplate. Sheet steel can be cut out to the contour of lay-out lines or superimposed templets. This machine

is intended for use where conditions do not warrant making a blanking punch and die for use on a power press.

NICHROME. Nichrome is an alloy composed of nickel and chromium, which is practically noncorrosive and far superior to nickel in its ability to withstand high temperatures. Its melting point is about 1550 degrees C. (about 2800 degrees F.). Nichrome shows a remarkable resistance to sulphuric and lactic acids. In general, nichrome is adapted for annealing and carburizing boxes, heating retorts of various kinds, conveyor chains subjected to high temperatures, valves and valve seats of internal combustion engines, molds, plungers and conveyors for use in the working of glass, wire baskets or receptacles of other form that must resist the action of acids, etc. Nichrome may be used as a substitute for other materials, especially where there is difficulty from oxidation, pitting of surfaces, corrosion, change of form, or lack of strength at high temperatures. It can be used in electrically-heated appliances and resistance elements. Large plates of this alloy are used by some manufacturers for containers and furnace parts, and when perforated, as screens for use in chemical sifting and ore roasting apparatus, for services where temperatures between 1700 degrees F. and 2200 degrees F. are encountered.

Strength of Nichrome. — The strength of a nichrome casting, when cold, varies from 45,000 to 50,000 pounds per square inch. The ultimate strength at 200 degrees F. is 94,000 pounds per square inch; at 400 degrees F., 91,000 pounds per square inch; at 600 degrees F., 59,000 pounds per square inch; and at 800 degrees F., 32,000 pounds per square inch. At a temperature of 1800 degrees F., nichrome has a tensile strength of about 30,000 pounds per square inch, and it is tough and will bend considerably before breaking, even when heated red or white hot.

Nichrome in Cast Iron. — Because of the irregularity of the castings, the numerous cores required, and the necessity for sound castings, gray iron with a high silicon content has been the best cast iron available to the automotive industry. Attempts have been made to alloy this metal in such a way that the strength and hardness would be increased, but considerable difficulty has been experienced in obtaining uniform results. Nickel has been added to the cupola with success, but in the case of automotive castings, where a large quantity of silicon is present, the nickel has combined with the silicon in forming large flakes of graphite, which, of course, softens the product. To offset this, chromium has also been added, but it has been uncertain just what the chromium content of the poured mixture should be, as a considerable amount of the chromium oxidizes.

Nichrome (Grade B) may be added to the ladle to obtain chromium and nickel in definite controllable amounts. The analysis of this nichrome

is, approximately: Nickel, 60 per cent; chromium, 12 per cent; and iron, 24 per cent. It is claimed that the process produces castings of closer grain, greater hardness, greater resistance to abrasion, increased durability, improved machineability, and decreased brittleness. Nichrome-processed iron is suitable for casting internal-combustion engine cylinders; electrical equipment, where a control of the magnetic properties is desired; cast-iron cams; iron castings of thin sections where machineability and durability are factors; electrical resistance grids; pistons; piston-rings; and water, steam, gas, and other valves.

NICKEL. Nickel is a grayish-white, malleable, ductile metal. In dry air, it remains unchanged, but oxidizes slowly in moisture in which acids are present. It resists the action of caustic soda, caustic potash, and concentrated nitric acid, but is readily dissolved by dilute nitric acid and aqua regia. Dilute hydrochloric acid and dilute sulphuric acid attack it very slowly. Nickel is used to a very large extent in the industries, especially in the manufacture of domestic utensils and for nickel-plating; it is also used for coins, and a number of alloys. Steels containing a small percentage of nickel have properties far superior to those of ordinary steel, while steels containing a very high percentage of nickel have been manufactured for special purposes. Nickel is obtained mainly from garnierite, the largest deposit of which is in New Caledonia, and from pyrrhotite, which is found principally in Canada, Germany, Sweden, and Norway. It is also secured from the by-products obtained by treating many pyrite and chalcopyrite deposits for sulphur or copper. The method of extracting the nickel depends upon the composition of the ore.

The specific gravity of nickel varies according to the method used for obtaining the metal; it has been found to be as low as 8.3 and as high as 9.25; an average commercial value is 8.8, giving a weight per cubic inch of 0.318 pound. Pure nickel melts at 1452 degrees C. (2646 degrees F.). The melting point of commercial nickel, however, varies anywhere from 1400 to 1600 degrees C. (from about 2550 to 2900 degrees F.). The specific heat averages 0.108 between 60 and 212 degrees F., and increases with an increase in the temperature. The thermal conductivity of nickel equals 14.2 (silver = 100) and the electrical conductivity, 12.9 (silver = 100). The linear expansion per unit length, per degree F., equals 0.00000695. Nickel is magnetic, but loses its magnetism when heated, and becomes entirely non-magnetic at a temperature of about 650 degrees F.

NICKEL ALLOY FOR RESISTING ACIDS. The resistance of nickel to acids is considerably increased by an addition of tantalum. Ordinarily from 5 to 10 per cent may be added, but the resistance increases with an increasing percentage of tantalum. An alloy of nickel with 30 per cent

tantalum, for example, can be boiled in aqua regia or any other acid without being affected. The alloy is claimed to be tough, easily rolled, capable of being hammered or drawn into wire. The nickel loses its magnetic quality when alloyed with tantalum. The alloy can be heated in the open air at a high temperature without oxidizing. The method of producing the alloy consists in mixing the two metals in a powdered form, compressing them at high pressure, and bringing them to a high heat in a crucible or quartz tube in a vacuum. For general purposes, the alloy is too expensive.

NICKEL-CHROMIUM STEEL. Nickel-chromium steel has, by both laboratory and practical tests, proved to be a very high grade steel. It is used on various classes of machinery that require a steel of high tensile strength, high elastic limit, and a great resistance to shock and torsional stresses. The properties which are given to steel by nickel and chromium, when used separately, are accentuated when nickel and chromium are added at the same time. A steel is then produced that possesses the very highest qualities that can be obtained with regard to strength, hardness, and ductility. The different combinations or percentages of the components of nickel-chromium steels are as varied as their makers. Thus nickel is used in percentages of from 1 to 5; chromium, from 0.5 to 5; carbon, from 0.25 to 0.45; silicon, when used, from 0.5 to 3; manganese, from 0.25 to 1.

Nickel-chromium steel must always be heat-treated in order to bring out the latent qualities of the annealed steel. It should be annealed after it has been worked and before heat-treatment, in order that it may return to its natural state of repose, as machining, forging, hammering, etc., is liable to throw it out of its homogeneity. The well-known Krupp armor-plate steel is a nickel-chromium steel containing about 3.25 per cent of nickel, 1.5 per cent of chromium, and 0.4 per cent of carbon. The value of this steel lies particularly in the fact that it does not crack even when deeply penetrated by a projectile. It is also used, to a great extent, for gears, and is the highest grade of steel on the market for this purpose. Another use is for automobile parts which require great strength and reliability.

S.A.E. Nickel-chromium Steels. — Nickel-chromium steels represent an important class in the automotive industry. The S.A.E. specifications cover nineteen compositions divided into four groups according to the nickel-chromium content. Steels from the No. 3115 to 3140 all have 1 to 1.5 per cent nickel; from 0.45 to 0.75 per cent chromium; and either 0.30 to 0.60 or 0.50 to 0.80 per cent manganese. The carbon range in this group is from 0.10 to 0.45 per cent.

Steels from No. 3215 to 3250 all have from 1.5 to 2 per cent nickel; from 0.90 to 1.25 per cent chromium; and from 0.30 to 0.60 per cent manganese. The carbon range is from 0.10 to 0.55 per cent.

Steels from No. 3312 to 3340 have the largest amount of nickel and chromium, the nickel range being from 3.45 to 3.75 per cent and the chromium, from 1.25 to 1.75 per cent. The manganese content in this group is from 0.30 to 0.60 per cent, and the carbon range is up to 0.45 per cent.

NICKEL IN CAST IRON. See Cast-iron Wearing Properties.

NICKEL PLATING. See Electro-plating.

NICKEL SILVER. See German Silver.

NICKEL STEEL. Nickel steel usually contains from 3 to 3.5 per cent of nickel (seldom over 5 per cent) and from 0.20 to 0.40 per cent of carbon. It combines great tensile strength and hardness with a high elastic limit and ductility. When properly heat-treated, it is much stronger than tool steel, but should not be used without heat-treating. Because of its combination of ductility, strength, and hardness, it is extensively used for armor plate, because it does not crack when perforated by a projectile. It is also used for ammunition, bridge construction, rails, etc., and in automobile building. An advantage claimed for nickel steel for rails is its increased resistance to abrasion. On sharp curves, it is estimated that a nickel-steel rail will outlast four ordinary rails. The combination of ductility with a high elastic limit makes this steel also valuable for shafting, especially for marine purposes where high and sudden stresses are frequently imposed upon the propeller shafting. It is suitable for parts requiring great strength, ductility, elasticity, abrasion and corrosion resistance — for example, axles, spindles, light-weight frames (such as for bicycles), rivets, gun barrels, armor plate, etc. It is easily cast and forged. When alloyed with chromium or vanadium, it is largely used for crankshafts, special spindles, automobile axle parts, etc. The strongest nickel steels are made from low-carbon steels.

Nickel steel can be purchased in almost any percentages of nickel up to 35 per cent, and with the carbon component varying between 0.10 and 1 per cent. If nickel is added to steel in any percentage not exceeding 8 per cent, the tensile strength and the elastic limit of the steel will increase with the percentage of nickel. If the percentage of nickel is above 8 per cent, but less than 15 per cent, its effect on the steel becomes entirely neutralized and brittleness is produced. If the nickel percentage, however, is above 15 per cent, then the strength and elasticity become practically equal to that of the nickel steels with percentages of nickel less than 8 per cent. If the nickel percentage is increased above 20 per cent, the strength and elastic limit gradually decrease, but the elongation increases. The United States Navy Department specifications for hot-rolled or forged nickel steel require the carbon content to be from 0.25 to 0.35 per cent, and the

nickel, from 3 to 3.5 per cent, with neither the sulphur nor the phosphorus exceeding 0.04 per cent.

NIGROSINE PAPER. Nigrosine paper, also known as black-print paper, is a material used for obtaining black lines on a white background by the process of blueprinting.

NIPPLES. Nipples are short pieces of standard pipe threaded on each end. When the threads run together at the center, the term " close nipple " is used; if a small amount of unthreaded surface is left in the center, the name used is " short nipple." Longer nipples are classified as " long " and " extra long," the latter varying from 4 to 12 inches, the length increasing by even inches. A *shoulder nipple* is a nipple of any length, which has a portion of pipe between two pipe threads. Generally, however, it is a nipple about halfway between the length of a close nipple and a short nipple. A *space nipple* has a portion of pipe or shoulder between the two threads. It may be of any length long enough to allow a shoulder. Nipples are either threaded right-hand or right- and left-hand.

NITER BLUING PROCESS. This is a method for giving articles of iron and steel a fine blue color by immersing them in molten nitrate of potash (niter), often called " saltpeter." See Bluing Steel.

NITRALLOY. Nitralloy is the general name of a number of special alloy steels which can be surface hardened by being subjected to the action of ammonia gas for a period of from two to ninety hours (depending upon the depth of case desired), while the material is heated to a temperature of approximately 875 degrees F., without subsequent quenching. Tests made upon nitrided steels have shown them to possess a remarkable resistance to metal-to-metal wear. Herbert pendulum tests, read in terms of Brinell numerals, indicate a minimum hardness several hundred points higher than the maximum hardness obtained with steels hardened by quenching. The nitrided case is fully as resistant as stainless steel to the corrosive action of fresh or salt water and moist atmosphere. See Nitrogen Hardening.

NITRIC ACID. Commercial nitric acid is yellow in color and has a specific gravity of about 1.4. It is one of the important mineral acids. It contains 68 per cent of the pure acid and boils at a temperature of 120.5 degrees C. (249 degrees F.). Nitric acid attacks most metals readily, its action depending usually upon the temperature and the strength of the acid. Concentrated nitric acid gives off red fumes when the acid acts upon most metals. Nitric acid has no effect upon gold, platinum, iridium, or rhodium. It solidifies at a temperature of -53 degrees F.

NITRIDING PROCESS. See Nitrogen Hardening.

NITROGEN. Nitrogen is a gas that forms approximately 79 per cent by volume, or 77 per cent by weight, of the atmosphere. The specific gravity of nitrogen (air = 1) is 0.967, and its atomic weight, 14.01. It liquefies at a temperature of −194 degrees C. (−317 degrees F.), and solidifies at a temperature of −210 degrees C. (−346 degrees F.). Its specific heat equals 0.244. Nitrogen neither burns nor supports the combustion of ordinary combustible materials. Nitrogen is produced in large quantities from atmospheric air in the commercial manufacture of nitric acid and nitrates.

NITROGEN HARDENING. Certain special alloy steels may be casehardened by subjecting the heated steel for several hours to the action of the nitrogen in ammonia gas. This gas process of casehardening is known either as nitrogen hardening or as a nitriding process, because of the use of nitrogen. The nitriding process is considered preferable to ordinary casehardening when a moderate surface toughness and particularly high resistance to wear are desired, together with freedom from distortion. For unusually high surface pressures, carburizing by the ordinary method is preferable to nitriding, owing to the greater carrying capacity of the hardened surface.

Steels Used. — Special steels developed by one steel manufacturer for nitriding have the general trade name of "Nitralloy." To satisfy various requirements as to core strength, nitralloy is produced in a number of different analyses. The addition of a definite percentage of aluminum in all types of nitralloy is absolutely indispensable, both on account of the extreme hardness which this element imparts, to the surface of the steel when subjected to the action of the nitrogen in the ammonia gas, and the desirable physical properties it produces in the core. Because of the fact that carbon has no influence on either the hardness or depth of the nitrided case, this element is present only for its effect on the physical properties of the core, and is used in smaller amounts than is customary in most alloy steels.

In typical nitralloy analyses, the amount of carbon ranges from 0.10 to 0.45 per cent, and the amount of chromium from 1.60 to 1.70 per cent. There may be no nickel or as much as 1.80 per cent. There is 0.60 per cent manganese, 0.25 per cent silicon, 1 per cent aluminum, 0.020 per cent sulphur, and 0.020 per cent phosphorus, and in the latest type of nitralloy, up to 0.25 per cent molybdenum.

Heat-treatment Previous to Nitriding. — Previous to nitriding, the steel is heat-treated to impart the desired physical properties to the core, after which the metal is machined as usual. All strains set up by forging or heavy machining operations must be thoroughly relieved by annealing. After nitriding, parts that have been annealed will be free from distortion or irregu-

lar growth in proportion to the care taken in carrying out the heat-treatment. All scale resulting from forging or heat-treating should be completely removed from the surfaces to be nitrided.

The Equipment Used. — The nitriding operation is preferably carried out in an electric furnace, the temperature of which can be closely controlled around 875 degrees F. The parts to be nitrided are placed in a gas-tight box which is provided with inlet and outlet tubes to permit circulation of the ammonia gas. Generally, an asbestos washer is used between the box and the lid, and asbestos packing is employed in the stuffing-boxes for the gas pipes. The latter are generally made of nickel, whereas the box and lid are either cast or built up from "Delhi" chrome iron. The parts to be hardened are placed loosely in the box without packing material, but the individual layers are separated by nickel wire netting to permit free circulation of the gas. The box with the gas connection is then rolled into the heating chamber and the door opening sealed. The flow of the gas is regulated by a needle valve furnished with the ammonia cylinder, which is connected by rubber tubing to the inlet pipe.

In the nitriding process, the two essential requirements are to keep the flow of ammonia fairly constant and to hold the temperature steady. The flow of ammonia can be looked after by the operator and rarely requires attention, whereas an automatic furnace control will take care of the temperature. Threaded and other sections of parts that must be kept soft can be protected from the nitriding action of the ammonia gas.

Depth and Hardness of Case. — The case produced by the full ninety-hour nitriding treatment is approximately 0.031 inch deep. About one-half of this case is of extreme hardness, the hardness decreasing gradually until the case merges into the core without any line of demarkation. The outermost part of the nitride case is not so hard as the zones immediately below it, and to get the best results, it is advisable to remove from 0.001 to 0.0015 inch from the diameter. This stock is usually removed with fine emery cloth or by buffing or grinding before the parts are put in service. For sections that must be produced to close tolerances, the nitriding process offers the advantage that the work may be finished practically to the desired dimensions without fear of material distortion during the hardening. In nitriding, there is a slight growth due to the absorption of nitrogen, but the change in dimensions is very slight. The growth can be allowed for in finishing the piece for hardening or it may be calculated to provide material for lapping operations after hardening, thus rectifying any slight movement caused by the presence of unrelieved strains. Inasmuch as the temperature at which the nitriding or hardening treatment is carried out is around 875 degrees F., the nitrided case retains its hardness when it is reheated, and remains file hard up to at least this temperature; hence, nitrogen hardening is particu-

larly suitable for parts that must withstand comparatively high temperatures and still retain the initial hardness.

Nitralloy steels forge as easily as ordinary alloy steels of the same carbon content. The low average carbon content, together with the small amounts of alloying elements present, produce ready machineability in rolled bars, forgings, and castings. Nitralloys are suitable for crankshafts, camshafts, timing gears, wrist-pins, worms, clutch and chuck parts, bushings, etc., and for many other parts of automobiles, calculating, adding and sewing machines, typewriters, shoe and textile machinery, etc.

NITROGLYCERINE. Practically all the higher explosives are based on "nitro," which is a chemical combination of glycerine and nitric acid, wherein the three hydroxyls of the glycerine are replaced by nitrogen oxide or some other organic substance with which the nitric acid can combine in a similar manner. Nitroglycerine is a heavy, thick, syrupy liquid. It has a specific gravity of 1.6, and its melting point is 13 degrees C. It has an intensely sweet taste, but is very poisonous, even in small quantities, when taken internally. The dose, when given internally, is only from 1/200 to 1/50 drop. Nitroglycerine is very sensitive to shock and friction, for which reason it is dangerous when frozen, as it must be thawed out before it can be used. A diluent has been found that will lower its freezing point without impairing its explosive power.

NOBLE METAL. This is a term applied to metals, such as gold, silver, and platinum. A *noble composition* is an alloy of two noble metals to which are added one or more metals as minor components.

NON-FERROUS ALLOYS. See Alloys, Non-ferrous; also various non-ferrous alloys, such as Brass; Bronze; Aluminum Alloys; Copper Alloys; Die-casting Alloys.

NON-GRAN BRONZE. Non-gran bronze is a gun-metal alloy. Its composition is copper, 86.5 per cent; tin, 11 per cent; and zinc, 2.5 per cent, with impurities which are less than 0.2 per cent. Non-gran bronze can be cast readily, and is also produced in bar form. The solid sizes range from ½ inch to 5 inches in diameter, by eighths of an inch, and the cored sizes from ½ inch to 3 inches inside diameter, by eighths. It is a good metal for non-adjustable bushings where the original dimensions must be preserved through long service. It is also adapted, on account of its resistance to wearing action, for high-speed gears and worms, and for feed-nuts, valves, etc.

Properties. — Weight, 0.31 pound per cubic inch; 536 pounds per cubic foot. Specific gravity, 8.6. Strength: tension, 37,000 pounds per square inch; compression, 19,500 pounds per square inch. Melting point, 2050 degrees F.

NON-METAL. A non-metal is a chemical element which does not possess the properties of a metal; that is, one that lacks metallic luster and which as a rule is nearly a non-conductor of heat and electricity; it is also electro-negative. There is no sharp demarcation, however, between metals and non-metals. The elements which cannot be defined strictly as being either the one or the other are known as *metalloids*.

NON-SPINNING ROPE. See Rope, Non-spinning.

NORMALIZING. Steel is usually annealed by first heating it to a temperature just above the critical range and then cooling it slowly. This temperatu e varies according to the carbon content, but usually varies from about 1400 to 1500 degrees F. Normalizing is a special annealing process. According to the S.A.E. definition, normalizing is the heating of iron-base alloys above the critical temperature range followed by cooling to below that range in still air at ordinary temperature. Annealing usually implies relatively to slow cooling. According to the British Engineering Standards Association, it is desirable that the normalizing temperature shall not exceed the upper limit of the critical range by more than 50 degrees C. (122 degrees F.). It may be necessary for annealing to hold the temperature for many hours or even days, whereas in normalizing it is sufficient to secure an even penetration of the heat throughout the material. Normalizing is intended to put steel into a uniform unstressed condition, and to obtain the proper grain size and refinement so that the steel will respond properly to further heat-treatment. Normalizing is particularly important in the case of forgings which are to be heat-treated later. This process may or may not leave the steel sufficiently soft for machining, as this depends upon the composition. Sometimes annealing for machineability is preceded by normalizing, and the final result is much better than would be obtained simply by annealing.

NORMALIZING, HEAT-TREATMENT. The following heat-treatment for normalizing plain carbon tool steel is recommended by the American Society for Steel Treating. Place the steel in a furnace so as to expose the maximum of the surface area to the heat. Heat uniformly to a temperature above the upper critical point, as given in Table 1, and hold the steel at this temperature for sufficient time to obtain complete penetration of the heat and complete refinement of the grain. To cool, remove the steel from the furnace and let it cool in the air. Table 1 gives the temperature to which the furnace should be raised for steel of different carbon contents. Table 2 gives the thickness of the largest section of the steel to be normalized, approximate weight in pounds of the piece of steel, the time required for bringing the steel up to the required temperature, and the time in hours that the steel should be held at this temperature before being removed from the

furnace. A normalizing treatment for all tool steels is recommended to obtain a uniform and refined grain structure.

Normalizing Plain Carbon Tool Steel

Table 1. Normalizing Temperature for Given Carbon Content

Per Cent Carbon	Temperature, Degrees F.	Per Cent Carbon	Temperature, Degrees F.
0.65 to 0.80	1475 to 1525	0.95 to 1.10	1500 to 1575
0.80 to 0.95	1475 to 1500	1.10 to 1.25	1575 to 1650

Table 2. Heating Data for Normalizing Carbon Tool Steel

Thickness of Largest Section, Inches	Weight of Piece, Pounds (Approximate)	Time of Heating, Hours (Approximate)	Time Heat is Held, Hours (Approximate)
Up to 1	Up to 100	$\frac{3}{4}$	$\frac{1}{2}$
1 to 2	100 to 300	$1\frac{1}{4}$	$\frac{1}{2}$
2 to 3	300 to 500	$1\frac{3}{4}$	$\frac{3}{4}$
3 to 4	500 to 1000	$2\frac{1}{4}$	1
4 to 5	1000 to 1500	$2\frac{3}{4}$	1
5 to 8	1500 to 2000	$3\frac{1}{2}$	$1\frac{1}{2}$

NORMAL PITCH. Normal circular pitch of a helical gear is the distance on the pitch surface along a helix perpendicular to the helix angle of the gear, from one tooth to the corresponding point of the adjacent tooth. (It is commonly miscalled the normal pitch.) Normal diametral pitch is that which corresponds to the normal circular pitch.

NORMAL RATING. The rate of discharge of a storage battery is the number of amperes that it will supply continuously for a given time, usually eight hours, three hours, or one hour. The 8-hour rate is called the normal rating.

NORMAL SALT. In chemistry, a normal salt is a salt in which one atom of hydrogen in each molecule is replaced by a metal.

NORTH BOLT. A North bolt is one which has a number of longitudinal grooves rolled into its body. This type of bolt is used largely on farming machinery and other agricultural appliances.

NUMBERS, PREFERRED. See Preferred Numbers.

NUT-DRIVING MACHINES. Machines for rapidly screwing and tightening nuts or bolts are adapted for duplicate assembling operations, especially where production is large. One design of a nut-driving machine has an air motor drive and a spindle speed of about 1000 R.P.M. Between the vertical spindle and the nut-driving end there is a friction clutch which can be adjusted so that it will slip whenever the nuts have been tightened sufficiently. By means of this clutch, each nut is automatically subjected to the same pressure or torque, and the machine can also be adjusted for driving nuts of different sizes. Below the friction clutch there is a positive two-jaw clutch through which the nut wrench is driven. When the machine is running idly, the nut wrench at the lower end of the spindle hangs free, and would remain stationary if gripped by the hand. When the spindle is lowered by a hand-lever, the upper half of the positive clutch engages the lower one, and the wrench, which is already resting on the nut, at the first touch of the upper clutch member, drops on the nut.

Removing Tightened Nut. — When a tightened nut is to be removed, more power is required at the instant of starting it backward than at any time while driving the nut on; consequently, additional tension must be applied to the friction clutch to keep it from slipping and thus prevent the machine from loosening the nut. This additional tension is provided automatically by a simple arrangement, consisting chiefly of a spring and an auxiliary clutch, each member of which has three jaws of spiral or helical form. These teeth are so shaped that the two clutch members are positively locked when driving a nut forward, but if the spindle is reversed when the lower section is retarded by a tightened nut, the spiral clutch teeth slide up upon one another against the tension of the spring which normally holds them in engagement. As the result of this expansion of the two clutch members, the spring is compressed and this extra compression subjects the friction clutch to additional pressure so that it will transmit enough power for starting the tightened nut backward at the instant of reversal.

Nut Held by Magnetism. — Another type of machine for driving nuts, cap-screws, etc., has two spindles, each carrying a detachable socket wrench in which the nut or cap-screw is held by magnetism. The drive to the main spindle is by belt either from a constant-speed motor or from a countershaft. The lower end of this vertical driving shaft carries the driving end of a magnetic clutch. The driven end of this clutch transmits, through differential gearing, motion to the two spindles, one of which is mounted on a slide for varying the center distance laterally. Below the spindles there is a bracket for supporting a table or fixture on which are held the parts to be assembled. This bracket is moved upward to bring a bolt, for example, in contact with the revolving nut above, by means of a foot-lever.

In operation, the nuts or cap-screws are placed in the stationary socket wrenches, and the parts to be assembled are located in the fixture in line with the spindles. As the foot-lever is depressed, the work-holding bracket moves upward and a swinging cam closes a switch, energizing the magnetic clutch and starting the spindles. As the foot-lever is further depressed, the nuts or screws are driven to a tightness predetermined by rheostat adjustment. When the magnetic clutch starts to slip, a mechanical switch opens the clutch circuit, releasing all torque on the spindles and allowing the work to be freely withdrawn from the wrenches by releasing the foot-lever.

Automatic Nut Feed. — A machine arranged to assemble nuts on automobile wheel hubs, but which may be used for setting nuts on any unit that can be conveniently moved under the spindle, is equipped with a hopper which automatically delivers nuts with the proper face upward to a trough. From this trough the nuts are forced into the spindle, one at a time, through an opening that registers with the end of the trough when the spindle is in the upper position. The nuts are forced down to the lower end of a socket wrench by a pusher inside the spindle, which also furnishes a solid backing for the top of the nuts and prevents the starting of cross threads. The operator merely lines up beneath the spindle the screw on which a nut is to be set, and then presses the foot-treadle. The spindle descends and engages the nut with the screw. Almost instantly, the nut is tightened on the screw to the required tension, which is predetermined by means of a friction clutch. Next, the operator allows the treadle to return, the friction clutch disengages, and the spindle returns to the upper position.

NUT STANDARDIZATION. There are several existing standards covering nut dimensions (widths across flats and thicknesses). These different standards are due in part to standardization development and partly to the fact that different industries have considered it advisable to have their own standards.

United States Standard. — This standard is found in many text books, and at one time was used almost universally. In the smaller sizes of hexagon nuts for automobile and similar purposes, it has been displaced by the S.A.E. Standard, which corresponds very closely with the American Standard for "Hexagonal Light Nuts." In square nuts the U. S. Standard has been almost entirely displaced except for very heavy service on the larger nut sizes. This standard has been applied more particularly in connection with railway work and machine tool construction. It was established in 1876 and was the first real attempt at nut standardization. The U. S. Standard has also been known as the Sellers or Franklin Institute Standard. The widths across flats for this standard equal 1.5 times the diameter of the bolt plus $\frac{1}{8}$ inch. The widths obtained by this formula exceed by $\frac{1}{16}$ inch

the widths of most of the nuts used at the present time. However, the greater width of the U. S. Standard doubtless was necessary when this standard was established, because nuts then were made of iron or welded scrap, which was weak in comparison with the steel which is used almost universally in modern nut manufacturing. The ordinary cold pressed hexagon steel nut will be found satisfactory as a substitute for the U. S. Standard hot pressed rough hexagon nut. U. S. Standard hexagonal and square nuts have the same width across the flats.

S.A.E. Standard. — Since lighter steel nuts may be substituted satisfactorily for the U. S. Standard, several lighter series have been adopted. One of the prominent light series is the Society of Automotive Engineers Standard for hexagonal nuts which has been used very generally by automobile manufacturers in the United States. This standard covers bolt diameters ranging from $\frac{1}{4}$ to $1\frac{1}{2}$ inches. The width across the flats equals $1\frac{1}{2}$ times the bolt diameter, excepting in some of the smaller sizes where slight variations are made to avoid dimensions to thirty-seconds inch. These nuts have the U. S. Standard form of thread but the pitch is finer than the U. S. Standard. The usual length of thread equals $1\frac{1}{2}$ times bolt diameter plus $\frac{1}{4}$ inch.

American Standard. — The tentative American Standard was approved by the American Engineering Standards Committee, February, 1927, and sponsored by the Society of Automotive Engineers and the American Society of Mechanical Engineers. This standard for rough and semi-finished square and hexagonal nuts and finished square and hexagonal nuts covers bolt diameters from $\frac{1}{4}$ to 3 inches inclusive. The width across the flats for rough, semi-finished and finished square and hexagonal nuts equals $1\frac{1}{2}$ times bolt diameter, excepting the bolt sizes from $\frac{1}{4}$ to $\frac{9}{16}$ inch inclusive. For these smaller sizes the width across the flats equals $1\frac{1}{2}$ times bolt diameter plus $\frac{1}{16}$ inch. Adjustments are made in the sixteenth-inch sizes to eliminate thirty-second inch widths. The tolerance for width across the flats of rough and semi-finished nuts is 0.050 times bolt diameter, this tolerance being minus relative to the nominal or basic width, which is maximum. The tolerance for finished nuts is minus 0.015 times bolt diameter plus 0.006 inch. This American Standard is intended to replace the U. S. Standard, the S.A.E. Standard, the Agricultural Implements Manufacturers' Standard, and the Manufacturers Standard, but evidently, these four standards will continue in use for a long time to meet special requirements and the demands of certain classes of nut users.

The American Standard for Hexagonal Light Nuts covers diameters from $\frac{1}{4}$ to $\frac{1}{2}$ inch inclusive. These light nuts are recommended for use with fine threads only. The widths across the flats are the same as the S.A.E. standard.

Manufacturers Standard. — The Manufacturers Standard covering rough and semi-finished square and hexagonal nuts was adopted October 4, 1927, by the Bolt, Nut and Rivet Manufacturers Association. This standard is based upon the American Standard for rough and semi-finished square and hexagonal nuts, but the $\frac{5}{8}$ inch and $\frac{3}{4}$ inch nuts have been made $\frac{1}{16}$ inch wider than the American Standard in order to allow the use of hot forged nuts, and the $\frac{9}{16}$ inch nut has been made $\frac{1}{64}$ inch thicker in order to permit the use of United States Standard $\frac{1}{2}$ inch material for this size. In other words, the width across the flats for square and hexagonal nuts equals $1\frac{1}{2}$ times bolt diameter, excepting the $\frac{1}{4}$ to $\frac{3}{4}$ inch bolt sizes, inclusive, when the formula is $1\frac{1}{2}$ times bolt diameter plus $\frac{1}{16}$ inch, adjustments being made in the sixteenth-inch sizes to eliminate thirty-seconds. The Manufacturers Standard is to be furnished by all manufacturers of the Bolt, Nut and Rivet Manufacturers Association, unless other nuts are specially ordered. Almost all nuts furnished with bolts which are sold to jobbers conform to the Manufacturers Standard, which is substantially the same as the sizes furnished by bolt manufacturers in the past. See also Bolt Head Standards.

NUTTALL STUB-TOOTH GEARS. See Stub-tooth Gears.

NUT-TAPPING MACHINES. Some of the most highly developed and ingenious tapping machines are used for tapping nuts. These machines are made in reversing and non-reversing types and may be hand-operated, semi-automatic, or fully automatic. Reversible machines are used for tapping nuts having closed ends which make it necessary to reverse the tap and back it out. The non-reversible machines may be so arranged that the nuts pass onto a long tap shank from which they are removed periodically, or the tap may be so held and driven that the tapped nuts pass over it completely without removing it or stopping the machine.

OAKUM. Oakum is used for calking seams of ships, stopping leaks, and by plumbers in the packing of joints such as the bell-and-spigot and Matheson types. Oakum may be made by untwisting tarry ropes and picking them into loose fiber. That made from untarred ropes is called "white oakum." In making a calked joint of the bell-and-spigot type, the oakum is forced into the joint with a yarning iron, and firmly calked with a calking tool; then molten lead is poured on top. The oakum should fill the bell of the joint to within about one inch of the top, because the really beneficial expansion of the lead, due to blows on the calking tool, is effective only through a comparatively small depth of lead. Additional metal is of no real value, merely filling space which the oakum might fill at less expense.

OBTUSE ANGLE. An angle larger than 90 degrees. See Angle.

OCTAHEDRAL BORAX. This is a form of borax suitable for use as a flux in soldering or welding. It is also known as jeweler's borax.

OCTOID GEAR TEETH. An octoid bevel gear tooth is formed when planing bevel gears on the Bilgram, Gleason, or other similar type of generating machines. In these machines, the teeth of the gears are shaped by a tool which represents the side of the tooth of an imaginary crown gear. The cutting edge of the tool is a straight line, since the imaginary crown gear has teeth the sides of which are plane surfaces. Theoretically, however, the sides of the teeth of a true involute crown gear are slightly curved: hence, the tooth formed by the generating machine is not an involute gear tooth, but has been called *octoid* by Geo. B. Grant. This form was invented by Mr. Bilgram. Both the octoid and the involute tooth give theoretically correct action.

ODD-LEG CALIPER. This is a caliper in which the points of both legs are bent in the same direction. A caliper of this type is used for measuring the distances between shoulders, and for similar work.

ODOMETER. An odometer is an instrument that is attached to the wheel of a vehicle for measuring the distance traveled by the vehicle, by recording the number of revolutions that the wheel makes in traversing the distance. When the circumference of the wheel is known, the approximate distance can be calculated. The instrument is used in engineering for preliminary surveying. In this case, the wheel to which the odometer is attached is generally made with a circumference of 10 feet. Maps are frequently prepared by the use of an odometer for measuring distance, the compass determining directions.

ODONTOGRAPH. An odontograph, in the limited sense of the word, is an instrument for laying out the forms of gear teeth, or a guide used in cutting gears to a given form in a gear-cutting machine. The term is, however, also applied to any method or table for laying out gear teeth by means of circular arcs which closely approximate the exact tooth curves. The most generally known, as well as the most accurate, of these odontographs is the one devised by George B. Grant. This odontograph consists of diagrams and tables giving the radii and location of the centers for arcs that approximate the true gear-tooth shape. These tables are found in engineering handbooks.

ODONTOMETER. The "odontometer" is a simple instrument or gage for testing the accuracy or uniformity of gear tooth profiles and spacings of the teeth in production work. It is equally adaptable to spur and helical gears and is self-contained. In general, the instrument is used as a comparator, to test the uniformity of interchangeable and mating gears. If actual measurements are required, the distance between the two parallel working faces of the instrument can be measured. The instrument is made so that a dial indicator is in full view of the operator as he rocks it over the teeth. Adjustment from one pitch to another can be made quickly.

O. D. PIPE. This is an abbreviation applied to large wrought or steel pipe, the nominal size of which is designated by the outside diameter instead of the inside diameter as in the case of smaller sizes. Ordinarily, pipes above the 12-inch size are listed according to the outside diameter, although at least one prominent manufacturer designates pipes above 15 inches by the outside instead of the inside diameter.

OERSTED. In a magnetic circuit, there is a certain tendency to limit the flux under a given magnetomotive force. This tendency is known as *reluctance*, and corresponds to the resistance in an electric circuit. The unit of magnetic reluctance is known as *oersted*, and is defined as the reluctance of a cubic centimeter of an air-pump vacuum. The symbol by which the oersted is generally known is R.

OGEE CAM CURVE. See Harmonic Motion Curve.

OHM. The unit of resistance to the flow of an electric current is known as an "ohm," and is equal to the resistance offered to an unvarying electrical current by a column of mercury having a mass of 14.452 grams (223.02 grains) at 32 degrees F., the column to be of constant cross-sectional area and to have a length of 106.3 centimeters (41.850 inches).

OHM'S LAW. The electric current that flows through a circuit is directly proportional to the electromotive force of the circuit and inversely

proportional to the resistance in the circuit. This relation is known as Ohm's Law, and may be expressed in formulas as follows:

$$I = \frac{E}{R}; \qquad E = IR; \qquad R = \frac{E}{I};$$

in which, I = current in amperes; E = electromotive force in volts; R = resistance in ohms

OIL, ACID NUMBER. See Acid Number of Oil.

OIL AND CHIP SEPARATORS. See Chip and Oil Separators.

OIL AND GAS ENGINES. See Internal Combustion Engines.

OIL BATH LUBRICATION. Oil bath or submerged lubrication, which consists in running parts in a bath of oil or grease which they continually stir up and spread over themselves, exists in many forms. In the oil bath as correctly arranged, there is never any lack of lubricant and the chief care is to see that no sediment is thrown up, or that any parts are shielded from the spread of oil.

OIL BONDING PROCESS. With the oil bonding process for grinding wheels, an oxidizing oil is mixed with the abrasive grains. After this mixture has thickened from exposure to the air, it is formed into wheels, by compressing it into molds by means of hydraulic presses. The molded wheels are then baked slowly at a low temperature. Oil wheels are similar in action to elastic wheels, but less dependable as to grade and uniformity.

OIL-BURNING FURNACES. The use of oil in furnaces for the heat-treatment of steel possesses, in many cases, certain advantages over other methods of heating. Chief among these advantages is the consideration of economy, as oil in the past, at least, has generally been cheaper to use than any other available form of fuel. The factor of economy is limited, however, by a somewhat increased complication in the method of operation, and, on this account, oil is not recommended for furnaces that will operate on gas with a consumption of 230 cubic feet per hour or less. The best results with oil-heated furnaces are secured with the larger-sized units. In those cases where the oil is atomized by steam, it is necessary to supply a certain amount of additional air in order to obtain the desired combustion. Steam is a chemical compound consisting of two parts of hydrogen and one part of oxygen and when the steam impinges upon the white hot brickwork of the furnace, the chemical union is broken, hydrogen and oxygen being liberated. The oxygen set free in this way is used in effecting the combustion of the oil, and the hydrogen is carried into the furnace. As hydrogen itself is a combustible gas, and is burned in the furnace by the oxygen of the additional

air which is supplied for this purpose, this combustion of hydrogen takes place further from the burner than the point at which the bulk of the oil is burned, and helps considerably in maintaining a uniform temperature. When the oil is atomized by a stream of compressed air, there is no hydrogen present to be burned in the furnace. Crude oil and kerosene are commonly used in oil-heated furnaces. To insure an unvarying temperature, the air and fuel pressures should be uniform. The two general types of oil-fired furnaces used are the over-fired type and the under-fired type.

OIL, COLD TEST. See Cold Test of Oil.

OIL COOLERS. A properly designed oil cooler will extract the greater part of the heat absorbed by oil from bearings and return the oil to the bearings at a comparatively low temperature. Cooling the oil permits it to absorb a greater amount of heat from the bearings, thus lowering the bearing temperature and at the same time decreasing the rate of evaporation. If the temperature is carried too low the increased viscosity of the oil will cause a slightly higher bearing friction and retard the rate of separation of water and other foreign matter.

The efficiency of the oil cooler depends upon the initial temperatures of the oil and water, the amount and rate of oil and water circulated, the mechanical design of the oil cooler and the cleanliness of the surfaces of the coils. The rate of heat absorption in the cooler depends largely upon the rate of flow of the oil film near to the metal surfaces. This rate of flow is again dependent upon the viscosity of the oil, all of which means that high viscosity oils require a much larger cooling surface than more fluid products for the same temperature reduction.

OILDAG. See Graphite.

OIL-ELECTRIC LOCOMOTIVE. See Locomotive, Oil-electric.

OIL EXTRACTORS. The oil that flows onto the cutting tools of automatic turning machines and other classes of machine tools, may be extracted from the metal chips or other foreign matter by means of an oil extractor or separator. The common design of separator intended for use in machine shops for recovering oil from chips is of the centrifugal type and is driven either by belt or by a direct-connected motor. See Chip and Oil Separator.

OIL FIRE POINT. See Fire Point of Oil.

OIL FLASH POINT. See Flash Point of Oil.

OIL GRINDING. Oil grinding is the final grinding to which steel balls are subjected in their manufacture, and by means of which the balls are brought to exact size. The oil-grinding operation is practically a lapping

process; no grinding wheel is used but the machine has two plates, one of which is grooved, between which the balls roll. The grinding is done with fine emery and oil.

OIL GROOVES. Oil grooves are cut into the surface metal of bearings to improve the distribution and efficiency of the bearing lubricant. It has been the general practice to cut oil grooves in both the top and bottom sections of the bearings, but experience has indicated that better results can be obtained by cutting the grooves in the upper half of the bearing only. Nothing should interfere with the suction of the oil from the low-pressure area to the area of high pressure, and it is a law of fluid friction that the friction between a solid and a fluid is increased with an increase in the roughness of the solid surface. For this reason, the "pull" of the journal surface, due to the adhesive effect between the oil and the journal, may be largely offset by oil grooving in the lower bearing surface.

Oil grooves should be at right angles to the direction of motion of the revolving or sliding part. The grooves should always be cut to a point a short distance from the outer edges of the bearing — never to the edge. There should be no sharp edges where the bearing is cut to make an oil groove, as these edges increase the wiping effect and may act as scraping edges. Oil grooves are expected to perform the following functions: (1) To hold the lubricant in the bearing; (2) to distribute the lubricant in a lateral direction (that is, sideways) over the surface of the bearing; (3) to return the lubricant that works over to the edge of the bearing towards the center.

OILING, RING METHOD. See Ring Oiling.

OILING SYSTEMS. See Lubricating Systems.

OILLESS BEARINGS. Oilless or self-lubricating bearings are especially adapted for applications in places where oiling is undesirable, or where the bearings are difficult of access, or likely to be neglected. They are of particular value in such plants as canneries, textile mills, etc., where the product is liable to harm from dripping oil, and oilless bearings are applied in many other classes of service. A number of different types of oilless bearings have been developed, each of which doubtless has its advantages when applied under suitable conditions. One type consists of wood impregnated with wax, oil or paraffin; another is made of bronze and has graphite inserts; another type is formed of graphite impregnated with some bearing metal such as a white alloy or bronze; and still another consists of hard maple reinforced by babbitt metal, the wood shell of which is impregnated with lubricants and thus serves as an oil reservoir.

OIL OF VITRIOL. This is a name sometimes used for sulphuric acid.

OIL QUENCHING BATHS. See Quenching Baths, Oil.

OIL-RING DESIGN. See under Ring Oiling.

OIL SEPARATORS. In order to purify the exhaust steam so that its condensation may be returned to the boilers, it is necessary to use some form of separator for removing the cylinder oil which it contains. There are various forms of separators in common use. In one type the entering steam is thrown downward upon an annular ring having a corrugated surface and an opening at the center. The outlet is downward from a point near the top. This construction completely changes the direction of the steam, reduces its velocity, and thus allows the particles of oil to be caught by the corrugations upon the annular ring or baffle. As the oil collects, it drips into the bottom of the chamber, from which it is trapped to the sewer or sump well through the drip pipe at the lower end. In another oil separator for non-condensing systems the separating surface consists of a baffle plate with vertical ridges, and ports at the sides for the passage of steam. The principle depended upon in the action of this separator is a sudden change of direction. The fact that the greater part of the oil contained in the steam runs along the lower surface of the pipes is taken advantage of, and the separator is so designed that it will break up the flow and drain the oil into a receptacle provided for it. The separators previously referred to are for use with non-condensing engines, where the pressure is slightly above that of the atmosphere. In cases of this kind, the oil is drained from the separator by means of an ordinary steam trap. When the engine is run condensing, in connection with a surface condenser, and it is desired to return the water of condensation to the boilers, it is evident that the oil cannot be drained from the separator in the usual manner because the pressure in the system is less than that of the atmosphere. Although the separator itself is practically the same, except in special cases, a special method of draining is required.

OIL SHALE. There are large deposits of oil shales in the western and southern parts of the United States, Colorado alone, according to an estimate, having enough oil shales to produce 20,000,000,000 barrels of oil and 300,000,000 tons of ammonium sulphate. The oil shale industry originated in England in 1694 but the chief commercial operations are in Scotland. One ton of shale yields from 1 gallon to 90 gallons of oil. In Scotland the average is about 23 gallons per ton. Gasoline obtained from shale oil contains large amounts of olefins and aromatic compounds and is inferior in quality as compared with gasoline obtained from petroleum.

OILS, MACHINE LUBRICATING. See Lubricants, Applications.

OILS, SLUSHING. See Slushing Oils.

OILS, SOLUBLE CUTTING. See Soluble Oils for Cutting Tools.

OIL STAINS ON CONCRETE. Oil stains on concrete floors may be removed by covering with a mixture of 1 pound of oxalic acid, 3 gallons of water and enough wheat flour to make a paste that can be applied with a brush. The paste is removed with clean water.

OILSTONES. The natural oilstones commonly used are the *Washita* and *Arkansas*. The Washita is a coarser and more rapidly cutting stone than the Arkansas, and is generally considered the most satisfactory for sharpening woodworkers' tools. There are various grades of Washita rock, varying from the perfect crystallized and porous whetstone grit, to vitreous flint and hard sandstone. The sharpness of the grit of any Washita stone depends entirely upon the character of its crystallization. The best whetstones are porous and uniform in texture and are composed entirely of silica crystals. The poorer grades are less porous, making them vitreous or "glassy." They may also have hard spots or sand holes, or contain grains of sand among the crystals. For general work, a soft, free-grit, quick-cutting stone is required, although a fine-grit medium-hard stone is sometimes preferable. Washita stones are sometimes white in color, but frequently streaked more or less with a yellow or red tinge. They are found in the spurs of the Ozark mountains of Arkansas. Many artificial oilstones are now used for various classes of work. These are commonly furnished in three grits: *viz.*, fine, medium, and coarse, and in all required shapes.

OIL SWITCHES. See Switches of Oil Type.

OIL-TUBE DRILLS. Twist drills are made having either small tubes imbedded in the sides of the drill and leading to the cutting end, or internal oil-holes which lead the lubricant directly to the cutting end. A special socket is used for an oil drill, having a stationary collar which is connected with a pipe and hose leading to the source of supply. This collar has an annular groove located opposite holes in the revolving socket, which permits the lubricant to enter holes in the drill shank.

OIL VISCOSITY. See Viscosity of Oil.

OIL-WELL CASING THREAD. The oil-well casing thread is made of the same form as the regular Brigg's standard thread, but the number of threads per inch for different sizes varies from the pipe-thread standard. For nominal sizes of from 2 to $4\frac{3}{4}$ inches, inclusive, 14 threads are used. From 5- to $7\frac{1}{4}$-inch nominal size, either 14 or $11\frac{1}{2}$ threads per inch are used. From $7\frac{5}{8}$- to $15\frac{1}{2}$-inch nominal size, $11\frac{1}{2}$ threads per inch are used. The taper of the thread on oil-well casings is $\frac{3}{8}$-inch per foot. Complete dimensions for oil-well casing gages will be found in leading mechanical handbooks.

OLDHAM'S COUPLING. Oldham's coupling may be used when two shafts to be connected are parallel, but slightly out of line. In this coupling each shaft end has a flanged hub attached to it, these flanges being keyed firmly to their respective shafts. Across the face of each of these flanges, a single groove, passing through the center, is planed, and between the ends of the flanges is interposed an intermediate disk which has a tongue on each side running diametrically across its face, these tongues engaging with the plain grooves in the faces of the flanges. The tongues in the intermediate disk are placed at right angles to each other; hence, when the shafts rotate, the motion can be transmitted from one shaft to the other at a uniform rate, although the axes of the two shafts are not in alignment.

"OLD MAN." An "old man" is the supporting bracket for the feed screw end of a ratchet drill. It consists of an L-shaped member which is usually bolted, or clamped to the part being drilled, and an adjustable arm against which the pointed end of the ratchet feed-screw bears. This device is also used with pneumatic and electric portable drills to provide "backing" or a resisting support for the drill.

OPEN-CIRCUIT CELL. This is a primary cell which will only supply current intermittently and then only for a short period of time, but which will stand on an open circuit for a long time without loss of materials through electrolytic action.

OPEN FEED-WATER HEATER. With this type of boiler feed-water heater, the exhaust steam used for heating mingles with the water in the same chamber; that is, the water is heated by direct contact with the steam, which condenses and mixes with the water. Some heaters of this type also act as purifiers and filters. See also Boiler Feed-water Heaters.

OPEN-HEARTH PROCESS. The open-hearth process, sometimes called "the Siemens-Martin process," is a method of producing steel by mixing pig iron with steel and iron scrap and removing the impurities contained in the bath of iron on the hearth of a regenerative furnace, the hearth being open or exposed to the action of the flame. The process is similar to the puddling process, but is carried out on a much larger scale. The gas and the air are heated to a high temperature (over 1000 degrees) before entering the combustion chamber, by passing through regenerative chambers. Owing to this preheating of the gas and air, a very high temperature can be maintained in the furnace so as to keep the iron liquid. The charge of molten metal has added to it a certain proportion of ore, iron scale or other oxides, the chemical reaction of which keeps the molten iron in a state of agitation. The process may be carried out by either the basic or the acid method. In the *basic*, or dephosphorizing, furnace, the slag is basic and the

furnace lining is neutral, but burnt lime is added to the charge to remove the phosphorus. In the *acid*, or undephosphorizing, process, there is a silicious slag and the furnace has a silicious lining, with the exception that the bottom lining of the furnace for both acid and basic processes is practically the same. The acid is the faster process, as the heat-insulating layer is comparatively thin; it is also the cheaper process, but this difference in cost is offset by the greater cost of pig iron and scrap free enough from phosphorus. The open-hearth process produces a more uniform and reliable steel and a greater yield of ingots from the metal charge than does the Bessemer process; and the operations are under greater control and samples can be frequently taken. Most of the structural steel used is made by the open-hearth process.

Open-hearth Furnace. — The furnaces for the open-hearth process of making steel are of various designs. Some are stationary, although many are arranged so that they can discharge their steel by being tilted, while others can be entirely removed from their setting and poured. They vary in size from 5 to 15 tons, for special grades of steel, and from 50 to 80 tons and upward, for standard grades; furnace units of from 50 to 60 tons are now generally preferred. The furnaces may be heated by natural gas, producer gas, or oil. The furnaces consist of a rectangular hearth with ports at each end through which the gas enters and leaves. Two chambers at each end provide means for heating the air and the gas. The roof of the furnace must be high enough so that it will not be burned by an impinging flame from the ports. The hearth must be of such a length, that there will be complete combustion; its length should be about two or two and one-half times its width; its depth should be sufficient to permit the oxidation of the metal, yet it should be sufficiently shallow to promote thorough heating, and reasonably quick working of the bath. Usually the maximum width of the hearth is about 15 feet, while the depth is about from 15 to 20 inches.

OPEN-HEARTH STEEL. As defined by the International Association for Testing Materials, open-hearth steel is any steel made by the open-hearth process, irrespective of the carbon contents. As a rule, however, open-hearth steel contains a smaller percentage of carbon than the steel generally known as *crucible* or *tool* steel.

OPEN-HEARTH TOOL STEEL. A large percentage of the steel used for making tools, if all classes of tools are considered, is produced by the open-hearth process. Open-hearth tool steel, however, is not recommended ordinarily for metal-cutting tools; in fact, either crucible or electric tool steel is specified by practically all manufacturers whenever the use of a dependable high-carbon steel of the best quality is considered essential.

Open-hearth tool steel meets all requirements for a large variety of tools

and implements which ordinarily are made from steels containing about 0.65 to 0.85 per cent carbon. These tools include hammers, sledges, pliers, woodworking tools, stone cutters' tools, picks, bars, axes, cheap knives, blacksmith tools, forging dies, agricultural implements, and numerous other products. The extensive use of open-hearth steel in the agricultural field accounts for the name "agricultural tool steel."

In attempting to make a direct comparison between steels made by the open-hearth process and either the crucible or electric process, it should be remembered that much depends upon the selection of raw materials and the care with which each process is conducted. Considering these steels as they are produced under ordinary commercial conditions, it is the general opinion of manufacturers that either crucible or electric steel is superior to open-hearth steel except for the general classes of tools mentioned, which are made from the relatively cheap open-hearth steel, as the latter meets all practical requirements.

OPEN-SAND CASTINGS. Rough castings, such as foundry plates, gaggers, etc., are usually made without a cope or other covering. Castings made in this way are known as *open-sand* castings. In preparing molds that are to be cast in this way, it is essential that they be level, as there is nothing to confine the metal which "seeks its level."

OPEN TAILSTOCK. This is a special design of tailstock for bench lathes in which the upper part of the spindle bearing is removed, so that the tailstock spindle may be readily lifted out of place. It is used on light delicate work which requires different tools to be employed. The open construction facilitates the rapid replacement of the spindle which holds the tool.

OPTICAL FLATS. Optical flats are glass disks made of a special brand of glass, whose surfaces are the nearest possible approach to perfect planes. Optical flats provide a simple and rapid means for checking surfaces that have been made very accurate by careful lapping. In testing such surfaces, all dirt or dust is first removed from both the glass and the work; then the optical flat is wrung on the work sidewise, with a slight pressure. If the lapped surface is sufficiently accurate, rainbow colored bands caused by the interference of light waves become visible across the working face of the optical flat. Ordinarily, lapped surfaces are passed as satisfactory if these interference bands are visible, but for exceptionally accurate work, the nature or formation of the bands is considered. Thus if a surface is perfectly flat, the bands extend across it in straight parallel rows, whereas the slightest amount of concavity or convexity would cause more or less curvature or irregularity of the bands. Optical flats intended for general testing of plane surfaces, as made by one manufacturer are $1\frac{3}{4}$ inches in diameter.

One grade is guaranteed to be accurate within limits of 0.000004 inch and another grade to 0.000008 inch. See also Light-wave Measuring Method.

OPTICAL INDEXING HEAD. See Indexing Head, Optical.

OPTICAL MEASURING TOOLS. Fixed gages and measuring devices of the purely mechanical type are used largely throughout the machine-building field, but optical methods are being applied on an increasing scale in connection with certain classes of measuring or checking operations incident to the manufacture or inspection of interchangeable parts, tools, etc. These optical devices for shop use are mostly of simple design and are not to be confused with scientific apparatus such, for example, as the interferometer, but nevertheless the extreme accuracy of some of the finely graduated glass scales, as well as the prisms and lenses used in these optical instruments for shop and tool-room use depends directly upon the more highly developed forms of optical apparatus. In the design of these tools, optical principles and methods have been utilized in different ways. Most of the instruments are provided with finely graduated scales and "spider" or "hair" lines on glass, in conjunction with means of magnifying the graduations so that readings or other observations may be readily made. The reasons for employing these optical appliances in preference to purely mechanical devices vary somewhat with different instruments, but, in general, the plan is to safeguard against errors that might otherwise result, either from wear, temperature changes, mistakes in checking readings, or variations due to the "feel" or pressure of contact between instrument and work. Some of these optical measuring tools are arranged for general use, and others are designed expressly for one class of work.

OPTIMETER. An "optimeter" may be described briefly as an optical indicator or comparator, which utilizes a microscope for magnifying the image of an exceedingly accurate glass scale which, through suitable reflecting means, enables the observer to obtain by direct reading the difference between the measurement of whatever gage or other part is being tested and the precision gage-block or other standard used in setting the optimeter to the zero position.

ORDINATE. In analytical geometry, the ordinate of a point is, generally, that coördinate which is measured parallel to the vertical axis. In mathematical expressions, the ordinate of a point is generally designated by the letter y. Whether the coördinate axes are parallel to each other or not, the ordinate is always measured along a line parallel to the vertical axis, and not along a line at right angles to the other axis. See also Abscissa.

ORE. An ore is a material that contains a metal in such quantities that it may be mined and worked commercially for that metal. In an ore, the

metal usually is contained in chemical combination with some other element, and, in addition, there are generally various impurities; hence, the condition in which the metal exists in the ore differs greatly. In all commercial iron ores, the metal occurs as an oxide, a carbonate, or a sulphide. The ore may be deposited in beds, lenses, or veins. *Beds* are masses of minerals found in solid stratas; *lenses* or *pods* are irregular masses of ore imbedded in, and separated by, earth or rock; veins fill crevices or seams and generally have quite well-defined walls. Ores having a high metal content are termed " rich "; those having a low metal content are termed " lean."

Commercial iron ore — oxide, carbonate, or sulphide of iron — contains from about 35 to 70 per cent of iron, together with impurities of phosphorus, silica (sand), etc. When ore contains less than 40 per cent of iron, it must first be concentrated, and when it contains less than 25 per cent of iron, it is not considered of any commercial value, because the cost of extracting the iron from the ore is too high to make it possible to sell the product in competition with that extracted from richer ores. The best iron ores are those in which the iron is combined with oxygen, forming an oxide ore. Ores which consist of carbonates, that is, minerals in which the iron is present in combination with carbon and oxygen, are also mined, and are of considerable importance, although they must be roasted to drive off the carbonic acid. The sulphide ores, that is, minerals in which the iron is present in combination with sulphur, are also used, but are of minor importance. These ores must be desulphurized in order to eliminate the sulphur. In fact, all iron ores, whether sulphides or otherwise, which contain sulphur to an amount exceeding one per cent, must be subjected to a special treatment before smelting. The three most important iron ores consisting of iron oxides are *magnetite*, *hematite*, and *limonite*. The carbonate iron ore is known as *siderite* and the sulphide iron ore as *pyrite*.

ORGANIC CHEMISTRY. In general, organic chemistry is the chemistry of carbon compounds. This definition is not absolutely true, as some carbon compounds, such as carbon monoxide, carbon dioxide, carbon disulphide, and silicon and iron carbides, are considered as inorganic substances; while some other substances, such as chloroform, which do not contain carbon, are treated as organic.

ORIFICE METHOD. This is a method of testing air compressors based upon the principle that if gas is allowed to pass from one vessel in which the pressure is high, through a small opening into a vessel where the pressure is low, the volume of gas passing through the opening in one minute is constant as long as the pressures are unchanged. This principle has been thoroughly investigated, and is used as the basis of many methods of measuring both gases and liquids. In the orifice method, the volume of air actually passing through the orifice is measured.

ORIGIN. In analytical geometry, the origin is the point where the coordinate axes intersect.

ORTHOGRAPHIC PROJECTION. See Projection.

OSCILLOGRAPH. The oscillograph is an electrical measuring instrument used for observing potentials or currents when the variations are too rapid to be indicated by other instruments. It may be defined as a galvanometer of very short period. It is used for the observation of potential waves of generators, potential and current waves in inductive apparatus, etc.

OSCILLOSCOPE. An oscilloscope is an optical-mechanical apparatus by means of which it is possible to observe the action of high-speed mechanisms under actual working conditions. With this device, the action of the mechanism, moving at high speed, may be studied as if it were moving very slowly or actually standing still. This is accomplished by the use of a special type of electrical lamp, the flashes of which are synchronized with the movements of the revolving mechanism. If the lamp flashes illuminate the moving part repeatedly at the same point in its travel, that point will appear stationary, because it is illuminated only at the instant when it passes a given position. If the successive flashes of the lamp illuminate the moving part at points slightly in advance of each other, the part will have the appearance of moving slowly. See also Vibroscope.

OSMONDITE. Osmondite is the constituent obtained in steel that has been drawn, after hardening, to a temperature of about 750 degrees F. This condition marks the boundary line between troostite and sorbite, troostite being developed by a lower drawing temperature, and sorbite, by a higher temperature.

OSTWALD CALORIE. The calorie or metric heat unit generally used in engineering is the kilogram-calorie, also known as kilocalorie or large calorie, which is equivalent to the heat required for raising the temperature of one kilogram of water one degree C. In electro-chemistry, a unit known as the *Ostwald calorie* is frequently used. This is equivalent to the amount of heat required for raising the temperature of one gram of water from 0 to 100 degrees C. One kilogram-calorie equals 10 Ostwald calories.

OTTO CYCLE. See Cycles, Internal Combustion Engines.

OUNCE METAL. This is an alloy widely used for pump bodies, valves, and similar parts. It is composed of 85 per cent of copper, 5 per cent of tin, 5 per cent of lead, and 5 per cent of zinc. It is also regarded as a good bearing metal for general service.

OVAL CHUCK. An oval chuck, also known as an elliptic chuck, is a work-holding device used in the lathe for holding and revolving work that

is to be turned to an oval or elliptic shape. The chuck is provided with a mechanism so that it will move the revolving work back and forth towards the tool in order to produce the elliptic shape.

OVERHEAD EXPENSES. The term "overhead" or "overhead expense" generally includes all items of cost that cannot be directly charged as wages of productive labor or as cost for materials used in actual manufacturing. Such expenses include such items as salaries of company officials and supervision in the shop, general office expense, office supplies, advertising, selling expense, traveling expense, losses from bad debts, power, light, heat, insurance, taxes, depreciation, general repairs, and shop supplies, shipping expense, storekeeping, purchasing, accounting, inspection, safety work, engineering and drafting-room expense, and research work. In different plants, there would evidently be different items that would have to be charged to overhead, but generally speaking, it includes costs that cannot be charged to productive labor and the cost of materials.

OVERHEAD EXPENSES, MAN-RATE DISTRIBUTION. The man-rate method of distributing overhead costs is the one in most general use because of its simplicity. To use this method, it is only necessary to find the ratio of total expenses to total labor for a given business, and to apply this ratio to the labor cost of each job. For a factory making one kind of product, this method of distributing overhead is quite satisfactory, but where the product itself is varied and the tools used in getting out the product are different for each of the various units produced, this method is incorrect and misleading as to final results. According to the man-rate method the highest paid workman requires the most overhead expense, when actually the lowest paid man often requires the most supervision, and frequently the machine tools used by the low-priced man are more expensive and require greater expenditures for operation and maintenance than those used by the skilled mechanic, because there is incorporated in the machine which enables lower grade labor to be used the skill that the high-grade man has in himself. Thus, if a semi-automatic machine is used for making any part, a man who is not an expert mechanic can be employed to run this machine or even several of these machines, but if this special equipment were not used a skilled man would be required to be in constant attendance on a simpler machine. It is obvious in this case that the overhead expense that is incurred in running the automatic machine is much greater in proportion to the wages paid the operator of these automatic machines than is the overhead incurred in running the mechanical equipment required by the skilled mechanic.

It is also true that even if the same wages were paid all men in a manufacturing establishment, it would still be wrong to apply the overhead to

each job on the basis of a percentage of labor cost, for we would still have the condition of one man running more machines than another and of the difference in cost of the machines operated; also that some men would be occupied on jobs such as cleaning castings, checking finished product, painting, etc., which require little mechanical equipment and therefore do not increase the overhead expense at the same rate as their wages increase the direct labor payroll. From the foregoing, it would appear that the man-hour rate method of distributing expenses is a dangerous one, in some instances. There are cases, however, where this method may give results which will be satisfactory from the standpoint of profit, as cited in the following:

In a manufacturing establishment where the mechanical equipment is fairly well standardized, where the product, while varied as to different types, still has the same average types of output, and where these types all require substantially the same machining operations, it will be found that the ratio of profit to total output will come up to expectations when the man-rate method of distributing overhead is used. There is also a factor that must not be overlooked when considering any business, and that is, the amount of information which the man or men at the head of it have of that business independent of records; frequently when estimating the cost of new work, allowances are made by the owner of a business for a higher expected cost due to special facilities which will be necessary and to the expectation that the bigger machines in the plant will be used on the work. By making such allowances, the final price submitted includes some of the factors of expense cost that are not actually subject to proof from any records of overhead expense which would be available if the man-rate method of distributing overhead were in use

OVERHEAD EXPENSES, MAN-HOUR DISTRIBUTION. The man-hour method of distributing overhead has for its base the number of hours spent on a job instead of the amount of wages paid. This method is subject to the same criticism as the man-rate method in that the assumption is made that the overhead expenses have a fixed ratio to the number of hours of time spent on a job. The advocates of this method point out that certain items of expense do bear a direct relation to the number of hours worked, and include under this head the expenses of the payroll and welfare departments, compensation, insurance, and supervision. To a certain extent these items do bear a closer relation to hours worked than to wages paid, but as they represent a small part of the total expense, and as it would be erroneous to distribute the major part of the overhead on this basis, there is no advantage in this method over the man-rate basis. Moreover, if it is the policy not to reduce the payroll and supervisory force every time

business falls off, the cost per man-hour would fluctuate sufficiently to nullify any advantage gained over the man-rate method, particularly where this advantage consists chiefly in compensating for the difference in labor rates by substituting hours worked for wages paid.

OVERHEAD EXPENSES, MACHINE-HOUR DISTRIBUTION. The machine-hour rate method consists of distributing all the manufacturing expenses of an establishment by a charge to each job of the overhead cost of operating the machines and other facilities used on that job. This overhead charge is not an average for the whole plant or department, but is, as nearly as possible, the actual overhead cost of maintaining and operating each of the machines, group of machines, benches, etc., which are found in the plant. By the proper use of this method it is possible to show the difference between the expense cost of a boring mill and a lathe, a gear-cutter and a splining machine, etc.

To install a machine-rate method, the number of feet of productive floor space available for manufacture is first found, eliminating the space used for foremen's offices, stairways, wash-rooms, stock-rooms, etc. The number of square feet so obtained is used as a devisor for determining the cost per square foot per year for maintenance, depreciation, taxes, insurance, and other kindred charges applying against the land and building. No expenses are included in this group that are incident to the actual operation of the machines, but only those charges that apply against the empty building ready for manufacture. However, the expense of lighting and heating the building and charges of a similar nature are included. In this way a charge per square foot is obtained which is practically the same charge as the owner of a building would make if he rented it and furnished the light, heat, and water used in the building, except that he would include a profit on his investment. The factory is divided into production centers, including in each center machines of a similar type located together, or individual machines where there are no convenient groups. Different kinds of machines should not be included in one production center, as this would defeat the object of the system. After the division into production centers has been made, the number of square feet occupied by each center is determined, including in this area the space required for the material waiting to go on the machines, the space required for the workman, etc., and each center is charged with a part of the rental of the whole building based upon the area occupied. This division gives the rent per year for each production center, and in this way the total charges of the building which we have called rental charges would be allocated to various production-centers. Thus it will be seen that one part of the expenses is now divided in such a way that these items can be included as one factor in the machine-hour rate.

The next step is to determine the actual cost of the expense items incident to the operation and maintenance of each of the production centers. These expenses consist of depreciation of the machinery and equipment, taxes, repairs, small tools, cutting oils and other charges which can be definitely allocated to the machines that have been included in one production center. If a small group of machines, all included in one center, requires the entire time of one foreman, the wages paid this foreman would be included with the other expenses in arriving at the total cost of operating the centers. The distribution of the power charge can best be made on the basis of the horse-power required by each production center. In this power charge we would include the expense of running the power plant as well as the shafting, belting, etc.

The expenses under consideration should cover a period long enough to insure correct results, as well as a period of normal operations so that the results will represent the hourly cost of operating the production centers in normal times and under normal conditions. The best results are obtained if the expenses for a whole year are used as a basis for the machine-hour rate; and if these expenses are carefully analyzed and allocated to the various production centers, the hourly rates first determined will not require much adjustment. In fact, the success or failure of the system depends on the amount of attention given to the division of the expenses at the beginning, as, unless the first rates are approximately correct, the first results obtained from the system will be so disappointing and misleading as to cause a manufacturer to condemn it and to insist for all time that the plan is no good. We will assume that the expenses analyzed cover a period of one year.

Two groups of the annual expenses are now divided among the various production centers, and by adding the rental charges and the charges for operating and maintaining the machines, we have the basis for determining the hourly cost of expense applicable to work on the machine-hour basis. To determine the hourly charge, the total normal hours which each production center will work per year is estimated; then the amount of the expenses allocated to each production center is divided by the normal hours this center should operate, and the result is expense cost per hour.

There still remain a few items of expense which have not been distributed, such as supervision, clerical, and general administrative expenses. These expenses should be totaled, and the total divided by the sum of the normal hours of all the production centers. The result of this is another hourly expense cost which must be added to each machine rate as a supplementary charge.

The machine-hour rate is based entirely on the assumption that the production centers will work a certain number of hours in a certain time, a year

having been used as the basis. It is obvious that no man can predetermine accurately the number of hours any machine in his plant will be occupied, and many people reject the idea of installing this system for that reason alone. However, a close approximation of the normal working time of any machine can be found, either by keeping records or examining records already available, and if the expenses of operating the machine are based on an approximately correct operating time, we have, by the machine-hour rate method, a means of showing immediately the financial effect of any variation of the operating time of the machines from the predetermined normal or standard operating time.

In making up the hourly rates, we assume that we had a certain amount of expense, say $1200, to absorb in a certain period, say one year, over one production center. Let us say that we estimated the normal hours that this center would be used in the year to be 2400, or 200 per month. On this basis, the hourly expense cost of operating this production center is fifty cents. By adding fifty cents for each hour that a job required the facilities of this production center, we would expect to absorb all the expenses connected with it. Now, if the jobs passing through this center in a month required the use of the facilities for only 180 hours, we would see at the end of the month that on this particular center we had failed to absorb $10 of our expenses. We would have the same information for all other centers, and, therefore, for the whole shop, and would know at the end of the month how much of the manufacturing facilities had not been used or had been used more than we expected, this information being available both in terms of hours and money.

When comparing the way in which expenses are distributed by machine-rate costs with the distribution by means of any other method, it will be seen that, as far as accuracy is concerned, everything is in favor of the machine-rate method. All other methods of absorbing manufacturing expense depend in one way or another on averages, and yet there is no more reason for averaging the expenses over costs of all the work produced than there is for averaging the material items.

OVERHEAD EXPENSES, MATERIAL AND LABOR DISTRIBUTION. The application of overhead on the basis of prime cost (material and labor) does not seem to be in very general use. This method requires that the total expenses of a business be divided by the sum of the direct labor and direct material and that the ratio or percentage so obtained be applied to the direct material and labor cost of each job turned out. It is manifestly wrong to apply this method to the product of a business that uses various kinds of material, but, where the product is all made from iron or steel, this method has some good points, as, by taking the material into consideration as well as the labor, we apply more accurately the expense of handling the

material in the shop which, of course, varies with the size of the piece handled.

This method has many of the same kind of inherent defects as the man-rate and man-hour methods, as we would still be applying an average expense to jobs instead of an actual cost, the difference between this and the other two systems being only that the material is added to the labor before determining the expense to be applied. Even were this method correct for some kinds of business, the places where it could be applied would be limited in number, and this method could never be applied generally.

OVER-HUNG BENDER. This is a bending machine for angles, channels, and other structural shapes in which the rolls are placed outside of the housing. These machines are not adapted for very heavy work, but the rolls are easily adjusted and can readily be taken off and replaced with rolls of a different shape.

OVERLOAD PREVENTION. Some types of machines are so arranged that any unusual resistance to motion will automatically stop either the entire machine or whatever part is affected, in order to prevent damaging the mechanism or straining it excessively. A simple form of safety device consists of a pin which shears off or breaks in case the overload becomes excessive. This method of protection against overload has been applied in various ways, and, while it is simple, there are certain disadvantages, one of which is that in order to avoid replacing a broken pin, the machine operator sometimes inserts a pin that is stronger than it should be. The ideal safety device is one which does not break in case of overload, but simply disengages and is so arranged that it can readily be reëngaged. In electrical work, this principle has been applied by substituting circuit-breakers for fuses which melt when the current becomes excessive.

Automatic Relief Mechanisms for Forging Machines. — Forging machines are equipped with a tripping or relief mechanism which prevents excessive straining or breakage of the parts controlling the motion of the movable die, in case the stock to be forged is not placed in the grooves of the dies, but is caught between the flat faces. These relieving mechanisms differ somewhat in design, but the object in each case is to temporarily and automatically release the movable die from the action of the driving mechanism, in case the operating parts are subjected to a strain or pressure that is abnormally high. The release may be obtained by inserting bolts or "breaker castings" in the mechanism, which will shear off or break if there is an excessive strain; another type of relief mechanism depends for its action upon a spring which is proportioned to resist compression for all ordinary strains but to compress sufficiently to release the pressure on the dies when that pressure increases beyond a safe maximum.

OVERLOAD TRIP. An overload trip is an arrangement which releases the holding latch of the circuit-breaker when the current, flowing through the circuit in which the breaker is connected, exceeds a certain predetermined amount, the tripping being accomplished by the armature of the magnetic circuit when forced against the holding latch by the attraction of the magnet.

OXALUMA. The trade name *oxaluma* applies to an aluminum oxide abrasive which is used for grinding materials of high tensile strength, such as soft or hardened steel, etc.

OXIDATION. One of the most common forms of chemical energy is *oxidation*, which is the combining of oxygen with various elements and compounds. The corrosion of metals is generally a form of oxidation; rust on iron, for example, is iron oxide. When oxidation becomes rapid, it is known as *combustion*, and the substances acted upon are termed " combustibles." When the combustion is extremely rapid and is accomplished with noise, it is termed *explosion*, and the matter that explodes is called an " explosive mixture."

OXIDIZING AND REDUCING AGENTS. Any substance that causes an element or compound to combine with oxygen is called an *oxidizing agent*. A substance that removes oxygen, or elements similar to it, is called a *reducing agent*. Reducing agents are especially useful in obtaining metals in the free state from their ores .

OXY-ACETYLENE METAL-CUTTING. See Cutting Metals with Oxidizing Flame.

OXY-ACETYLENE WELDING. The high temperature required for autogenous welding is obtained usually by the combustion of acetylene gas and pure oxygen. These gases are thoroughly mixed in the nozzle or tip of the welding torch to insure perfect combustion. The weld may be formed directly between two adjoining surfaces, but usually metal from a welding rod is fused in between the surfaces of the joint. The rod or wire used may or may not have the same composition as the material being welded.

This welding process may be applied to cast iron, steel, brass, copper, aluminum and other ferrous and non-ferrous metals. For ordinary welding operations the equipment consists of containers for the oxygen and acetylene gases, with suitable reducing valves, pressure gages, and hose connections with the welding torch. In manufacturing plants where oxy-acetylene welding or metal-cutting apparatus is used more or less continuously, and especially on duplicate work in quantity, special tools, fixtures and machines are employed for holding the work and guiding the torch mechanically

Oxy-acetylene Flame. — The combustion of acetylene in oxygen produces an extremely high heat. The temperature produced by the oxy-acetylene flame is estimated at about 5400 degrees F. The flame of acetylene is much hotter than that of hydrogen, and the number of heat units per cubic foot of gas is about five times as great, the ratio being as 330 to 1600. Hence, both the intensity and amount of heat of the oxy-acetylene flame, as compared with other heat-producing mediums, are superior. The oxy-acetylene flame is used for cutting metals, in addition to its use for welding. When iron and steel are heated to a high temperature, they have a great affinity for oxygen and readily combine with it to form different oxides, which cause the metal to be disintegrated and burned with great rapidity; this is the principle governing the operation of a cutting torch. See also Cutting Metals with Oxidizing Flame.

Preparing Work for Welding. — It is generally essential that a weld be made through the whole section of a break; sometimes this is not necessary, and in exceptional cases it may be impossible. In order to secure a weld through the whole section, some preparatory work must be done. For ordinary work, it is sufficient to bevel the edges of the broken parts so that when placed together the included angle will be 90 degrees. Enough of the old break is left to enable the parts to be correctly set for welding. The reason for opening the break to a 90-degree angle is to permit the flame of the torch to reach the bottom of the V. It is especially important that the 90-degree angle be maintained in preparing steel parts for welding. Instead of beveling only from one side, it is preferable to bevel the work from both sides, when possible, resulting in a double V; then only half the welding of a single V is required, and a better weld is produced.

Preheating. — The general principles involved in preheating may be briefly stated as follows: Parts to be welded autogenously are often preheated by the use of a blow-torch, gas furnace, charcoal fire, etc. This preheating is done either to economize in gas consumption or to expand the metal before welding, in order to compensate for contraction in cooling. Usually it is advisable to preheat comparatively heavy, thick metals (especially if cast) before welding. This equalizes the internal strains, and materially reduces the cost. In many instances, it is much better to produce expansion before welding than to attempt to care for the contraction afterward.

Welding Materials. — In nearly every case of oxy-acetylene welding, it is necessary to use additional material to fill up the V left by the beveling of the work. The kind of material used for this purpose varies with the metal being welded, but, whatever the quality, it is, in almost all cases, furnished in the form of wire or rods from $\frac{1}{16}$ to $\frac{3}{8}$ inch in diameter. For welding cast iron, the material used is cast-iron rods from $\frac{3}{16}$ to $\frac{3}{8}$ inch in diameter, the

small rods being used for small work and small tips, while the heavier rods are for the larger work and heavy tips. In welding steel, nothing but the best and most suitable wire should be used. Wire purchased at an ordinary hardware store is of no value, as it is of improper composition, being frequently high in sulphur and phosphorus and, often, too high in carbon also; hence, it will not give good results. The use of Swedish iron or any pure iron wire gives good results, and, until the matter is more carefully investigated, one is safe in using that material.

Some kind of a flux is generally also required for most welding, different kinds of fluxes being used for different metals. In the welding of steel, a flux is not ordinarily used. In oxy-acetylene welding, follow strictly the instructions given by the manufacturers of the apparatus used.

Welding Thin Sheet Metals. — The welding of very thin sheets by the oxy-acetylene process can be facilitated by turning over the edges of the sheets to an angle of 90 degrees. The application of the welding flame to both flanges simultaneously serves to fuse one flange with the other, thus effectively joining the two sheets. Vary the distance of the torch tip from the work according to the thickness and kind of metal being welded. For aluminum, the distance of the tip from the metal should be from $\frac{1}{4}$ to $\frac{3}{4}$ inch; for brass or copper, from $\frac{3}{16}$ to $\frac{3}{8}$ inch; and for iron or steel, from $\frac{1}{16}$ to $\frac{1}{8}$ inch. Exercise care in selecting a tip of the correct size for the work to be done.

Copper and aluminum are first-class conductors of heat, and consequently, more heat is required than for metals of the same thickness that are poor conductors. For instance, in welding $\frac{1}{8}$-inch copper or aluminum, it is necessary to use a torch capable of welding $\frac{3}{16}$-inch iron or steel. When welding sheet metal less than $\frac{1}{8}$ inch in thickness, direct the torch flame on the material at an angle of from 45 to 50 degrees instead of at right angles to the work. To prevent undue expansion or distortion of the metal, use heat conducting blocks or sheets — preferably of copper — on each side of the joint. Don't use an unduly large amount of heat when welding thin sheet metal. Light weight material that is overheated will show a tendency to buckle as the sheet cools.

OXYACID. Oxyacid is an acid which contains oxygen. Its name is generally formed by adding " -ic " either to the name of the element with which the oxygen is united or to an abbreviation of that name, as, for example, sulphuric acid and phosphoric acid. If the element forms two acids with oxygen, that which contains less oxygen usually ends in " -ous." The acid which contains still less oxygen than one ending in "-ous," is designated by the prefix " hypo-"; those containing more oxygen than one ending in "-ic " are designated by the prefix " hyper-" or " per-."

OXYGEN. Oxygen is one of the chief constituents of the atmosphere, in which it is present to the extent of 21 per cent by volume or 23 per cent by weight. The atomic weight of oxygen, which is taken as 16, is used as a standard by which the atomic weights of other elements are compared and determined. The specific gravity of oxygen (air = 1) is 1.106. Its specific heat at 32 degrees F. is 0.217. It becomes liquefied at a temperature of −183 degrees C. (−297 degrees F.), and solidifies at a temperature of −235 degrees C. (−391 degrees F.). Oxygen does not itself burn, but it is the greatest supporter of combustion known, and nearly all other chemical elements combine with it under evolution of heat. Oxygen is used in many industries; in the machine industries, it is used in large quantities for oxy-acetylene and oxy-hydrogen welding of metals and cutting of iron and steel.

OXYGEN AND NITROGEN IN STEEL. Oxygen and nitrogen are very injurious to steel and decrease its strength and wearing qualities. When titanium is added to the molten metal, it combines with these gases, which otherwise are liable to become occluded in the steel, and carries them off into the slag. These gases also form miniature bubbles that, when segregated, form holes large enough to be seen plainly. If segregated in large enough masses they form good-sized blow-holes. Owing to the gaseous nature of both oxygen and nitrogen, it has been difficult to analyze steels for these contents. Investigations, however, showed that the percentage of oxygen in some twenty-four samples of steel ranged from 0.021 to 0.046 per cent. Even these small percentages are high enough to materially effect the qualities of steel.

Investigations have shown that, at first, an increase of nitrogen causes the toughness of steel to slightly increase, but reduces its ductility; each increase of nitrogen causes the elongation to rapidly diminish. Steel with 0.5 per cent of carbon loses its ductility in the presence of from 0.040 to 0.047 per cent of nitrogen. Open-hearth steel usually contains from 0.020 to 0.025 per cent of nitrogen; Bessemer steel from 0.018 to 0.062 per cent; and crucible steel has from 0.010 to 0.015 per cent in nitrogen. Titanium has a very strong affinity for both oxygen and nitrogen; it forms with oxygen an oxide, and with nitrogen, a stable nitride that shows as tiny red crystals under the microscope. Both of these are then carried off into the slag and the quantity of slag that is lifted from the molten metal is quite materially increased. The deoxidation of steel is usually accomplished with manganese and silicon, but these never remove the oxides as thoroughly as is desired. Titanium is a much more powerful deoxidizer than either or both of these; when added to steel at the time of tapping, it completes their unfinished work and reduces the oxygen and nitrogen to mere traces.

OXYGRAPH. The oxygraph is a machine used for cutting steel by the oxy-acetylene process, and is employed when it is required to follow a certain outline or pattern. The device is constructed on the pantograph principle.

OXY-HYDROGEN FLAME. Hydrogen gas burns readily in oxygen or air. When the combustion of hydrogen is sustained by pure oxygen, a very high temperature (about 4000 degrees F.) is produced. Many forms of oxy-hydrogen lamps and blowpipes have been invented to make use of the high heat produced by the combustion of hydrogen. The flame is used for autogenous welding and cutting of metals and in platinum works, because the latter metal is fusible only in the oxy-hydrogen or oxy-acetylene flame and in the electric furnace. The oxy-hydrogen flame, or, more properly speaking, the air-hydrogen flame, is used extensively in lead burning, which is a process similar to that used for the welding of iron, steel, and other metals, by means of the oxy-acetylene flame. Hydrogen — with air to sustain the combustion — is used for lead burning instead of acetylene, because lead melts at a low temperature, and the high heat produced by acetylene burning in oxygen makes the welding of lead by it very difficult, if not impossible. Air is also used instead of pure oxygen for the combustion of the hydrogen in order to reduce the temperature of the flame.

OZONATORS. An ozonator or ozonizer is an electrical apparatus for producing ozone for the purification and deodorization of air under various conditions. The essential parts of an ozonator are the transformer for obtaining a sufficiently high voltage and the generating units.

PACK-HARDENING. Pack-hardening as usually conducted is actually carburizing, the only departure from the process, in general, being that the temperatures of the heats are lower. Correctly speaking, pack-hardening is the process whereby high-carbon steels or steels that will harden without the aid of carbon added by carburizing, may be protected from furnace gases and air. By packing in some carbonaceous material, the work is protected by the carbon gases given off, and in quenching from the pot, the work is clean and free from scale. A valuable point in favor of this operation is that the work is brought to the quenching temperature slowly and uniformly, and so dangers of cracking and warpage are reduced to a minimum. Any carburizer can be employed in packing, used material being the best, as the carbon strength of the gas is lower and there is less danger of carburizing the work. The danger of decarburizing is slight, provided the lowest temperature that can be used for hardening the work is employed. The length of time of the operation has a tendency to increase the grain size, which is augmented by high temperatures. It is dangerous to carburize the surface of high-carbon steel, because a line of demarcation between the case thus produced and the case of the original steel will shorten the life of the part. Minute surface cracks usually develop after hardening.

Common hard wood charcoal is recommended for pack-hardening, especially if it has had an initial heating to eliminate shrinkage and discharge its more impure gases. The work is packed as in carburizing and in the same type of receptacle. The pack-hardening of high-speed steels is extensively done. There are many tools which are so delicate and have such a variation in cross-section that only with extreme care can they be hardened in the open furnace and preserve the delicate edges and corners.

PACKING. Packing is used on engines, pumps, and machinery of various classes to seal joints either between stationary or movable parts, in order to prevent the leakage of steam, air, water, or any other gas or fluid. Packing is made in many different forms and is applied in various ways. For instance, packing in the form of thin sheets or rings of some flexible material is placed between pipe flanges, cover joints, etc., to prevent leakage. Other forms, which may be of square or circular cross-section, are applied to valve stems, engine piston-rods and in general, wherever a tight joint is required. A great variety of materials are used for packing, the particular material used depending somewhat upon the class of service and also upon the preference of the designer or engineer. Whatever the composition may be, the essential qualities are elasticity, durability, and, in the case of packing for a moving part, a low coefficient of friction and practically no wearing or abraiding effect.

PACKING MATERIALS. The packing materials formerly used were hemp and cotton fiber, but much of the packing now used for certain classes of service is made of combinations of cotton (in the form of canvas) with rubber. The rubber provides the necessary elasticity and the canvas absorbs and holds the lubricant. Paper fiber has also been extensively used, as well as hemp with graphite. For some purposes, these fiber and rubber packings have been inadequate, either because of high pressures or high temperatures. In order to secure a more durable packing and one that would resist both heat and an excessive pressure, the metallic form of packing has been extensively used, especially for steam engine piston-rods. There is a great variety of packing adapted to steam work which may be classified as fibrous and metallic, although it may be combined in many different ways, together with rubber, graphite, and other materials. The metallic packing is formed of a series of rings composed of some soft alloy, and so arranged that end-wise compression, from a gland or spring within the gland, will cause the rings to contract upon the rod.

There are various forms of shredded packing, both metallic and fibrous, which are mixed with certain lubricating substances and packed in the stuffing-box. Packing of this kind is also put up in thin cotton tubes, two or three feet in length, which are wound around the rod the same as wicking. Ring packing made up of various substances is a very efficient and convenient form. Packing rings are usually cut on a bevel and spread apart sufficiently to slip over the rod, enough being used to fill the stuffing-box to the required depth.

PAINT, ALUMINUM. See Aluminum Paint.

PAINT, HEAT-REFLECTING. See Aluminum Paint; also Acalorin; also Radiation of Heat.

PAINT, HIGH-TEMPERATURE. Paint that will withstand high temperatures, even up to a red heat, has the following composition: Lampblack, 3 pounds; graphite, 3 pounds; black oxide of manganese, 1 pound; Japan gold size, 1 pint; turpentine, 1.5 pint; and boiled linseed oil, 1 pint. Powder the graphite and mix all the ingredients to a uniform consistency; give two coats. The following mixture is also recommended: Black oxide of manganese, 2 pounds; graphite, 3 pounds; and terra alba, 9 pounds. Mix and pass through a fine sieve, then mix to the required consistency with the following compound: Sodium silicate, 10 parts; glucose, 1 part; and water, 4 parts.

PAINT, RADIATOR. See under Radiation of Heat.

PANEL OR THICKNESS PLANER. This type of wood-working machine is also known as a "surfacer" and may be either single or double,

depending upon whether it operates on one or on both sides of the board at the same time. It does not make a plane surface, as the stock is fed through rollers which hold the piece straight while the cutters are in operation, but the work resumes its original form as soon as the pressure is relieved. The single type used in combination with the hand jointer is the best for pattern-shop work. The stock is first jointed on one side and planed to thickness on the panel planer.

PANTOGRAPH MECHANISMS. A pantograph is a combination of links which are so connected and proportioned as to length that any motion of one point in a plane parallel to that of the link mechanism will cause another point to follow a similar path either on an enlarged or a reduced scale. Such a mechanism may be used as a reducing motion for operating a steam engine indicator, or to control the movements of a metal cutting tool. For instance, most engraving machines have a pantograph mechanism interposed between the tool and a tracing point which is guided along lines or grooves of a model or pattern. As the tracing point moves, the tool follows a similar path, but to a reduced scale, and cuts the required pattern or design on the work.

PAPPUS RULE. See Guldinus Rules.

PARABOLA. The parabola is a curve of that class known as *conic sections*. The parabola is obtained by taking a section through a cone parallel to the side of the cone. If a parabola rotates about its own axis, the parabolic curve will describe a surface which includes a solid body known as a *paraboloid*.

PARAFFIN-BASE OILS. See under Lubricants.

PARAFFIN MOTORS. The power obtained with paraffin motors is about 10 per cent less than with gasoline, and the consumption is from 0.7 to 0.8 pint of paraffin (specific gravity, 0.82) per horsepower-hour. The normal speed varies from 500 to 800 revolutions per minute with the size of the motor, and the motor can be run down to one-fourth the normal speed. Paraffin carburetors, for running a gasoline engine with paraffin, are not entirely satisfactory. In the paraffin motor, the vaporizer is usually heated by the exhaust gases, and the engine is started on gasoline, or the vaporizer is heated up by a blast lamp. A lower compression is used than in gasoline motors.

PARALLEL CONNECTION. In electric batteries, when all the anodes or positive electrodes of a battery are connected together and all the cathodes or negative electrodes are connected, this is known as a parallel connection. With such a connection the result is the same as if the battery were a single

cell having elements of the same area as the area of the combined anodes and combined cathodes. The electromotive force is the same as that of one single cell, but the resistance of the battery will be that of one cell divided by the number of cells; hence, the amount of current is increased, being equal to the current of one cell multiplied by the number of cells. See also Battery Voltage.

PARALLELEPIPED. A parallelepiped (sometimes also called *parallelepipedon*) is a solid body bounded by six plane surfaces, all of which are parallelograms. Each two opposite surfaces are parallel and equal to each other. A parallelepiped may also be defined as a prism, the end surfaces or bases of which are parallelograms.

PARALLEL MOTION. See Straight-line Motions.

PARALLELOGRAM. A plane figure bounded by four straight sides, of which those opposite each other are parallel, is known as a *parallelogram*. The square and rectangle are parallelograms in which all of the angles are right angles. It is not necessary, however, that the angles be right or 90-degree angles; sometimes two of the angles are less and two more than 90 degrees. The sum of the angles, however, is always equal to four right angles.

PARALLEL PLANER DRIVE. Some planers of the spur-geared type have the belt pulleys mounted on a shaft which is parallel with the bed and is connected with the pinion driving shaft through bevel gearing. This arrangement permits the planer to be located parallel with the line-shafting, and is often referred to as a *parallel drive*.

PARALLELS. Parallels are placed beneath parts to be planed or ground, usually for the purpose of raising them to a suitable height, or to align a finished surface on the under side with the platen, when such a surface cannot be placed in direct contact with the platen. These parallels are made in pairs of different sizes, and opposite sides are parallel to each other.

PARAMAGNETIC SUBSTANCE. If a substance has a magnetic permeability greater than that of air, it is called a paramagnetic substance. Most substances are very slightly paramagnetic, but the only substances that are strongly paramagnetic, that is, that have a permeability considerably greater than that of air, are iron, steel, nickel, and cobalt, and certain of their alloys. A paramagnetic substance is the opposite of a diamagnetic substance, which latter has a permeability less than that of air. The only known substance that is diamagnetic in a measurable degree is bismuth. All the elements except iron, steel, nickel, cobalt, and bismuth are generally considered to be non-magnetic.

PARENTHESES. Two important rules relating to the use of parentheses are based upon the principles of positive and negative numbers:

1. If a parenthesis is preceded by a + sign, it may be removed, if the terms within the parentheses retain their signs.

$$a + (b - c) = a + b - c.$$

2. If a parenthesis is preceded by a − sign, it may be removed, if the signs preceding each of the terms inside of the parentheses are changed (+ changed to −, and − to +). Multiplication and division signs are not affected.

$$a - (b - c) \quad = a - b + c.$$
$$a - (- b + c) = a + b - c.$$

PARKHURST WAGE SYSTEM. See Wage System, Parkhurst.

PARSONS' WHITE BRASS. This is an alloy of tin, zinc, and copper, frequently known as "Parsons' white bronze." This alloy has the essential characteristics of hard babbitt.

PARTING SAND. Parting sand is a fine shore or river sand used in molding to prevent adjoining bodies of sand from adhering. It is sprinkled on the joints of molds to prevent the sand in the cope and drag from adhering to each other.

PARTZ CELL. A Partz cell is a primary cell or battery having a zinc anode, a carbon cathode, and an electrolyte consisting of a solution of common salt or magnesium sulphate, with a bichromate depolarizer. It may be used for open or closed circuits and will develop an electromotive force of from 1.9 to 2 volts.

PASSOW CEMENT. A cement known as Passow cement is made by granulating blast furnace slag and finely grinding the product, either alone or with an addition of about 10 per cent of Portland cement clinkers. Passow cements are claimed to produce a material which sets rapidly and which attains a strength comparable with that of Portland cement.

PASTE BINDER. This is a paste made of flour and water, used for holding together the sand in dry sand cores. This binder is especially used for long, slender cores.

PATCH BOLT. A bolt provided with a countersunk head on the top of which a square head is provided; such bolts are used for fastening patches in the repair of boilers. Holes in the patch or plate are countersunk for the heads of the bolts and the boiler plate holes are tapped. After the bolts have been screwed securely into place, the square heads are removed, and the bolt heads and edge of the plate are calked to prevent leakage.

PATCH-BOLT TAPS. Patch-bolt taps are only a modified form of taper boiler taps. The taper is the same, $\frac{3}{4}$-inch per foot, but the threaded portion as well as the total length is shorter than the corresponding lengths of a taper boiler tap. Patch-bolt taps are always provided with 12 threads per inch irrespective of diameter.

PATENT. A patent is issued by the United States Patent Office to any person who has invented or discovered any new and useful art, machine, method of manufacture, composition of matter, or any new and useful improvement along these lines. In order to obtain a patent, the invention must not have been known or used by others in this country previous to the time the invention was made by the person applying for the patent; nor must it have been described in any printed publication in the United States or any foreign country before the invention was made by the person applying for a patent in this country, or more than two years prior to the application for a patent. A patent cannot be granted if the article has been in public use or for sale in the United States for more than two years prior to the application for a patent. A patent contains a grant to the patentee, his heirs or assigns, for a term of seventeen years, for the exclusive right to make, use or sell the invention or discovery throughout the United States.

A United States patent is a monopoly created by law and it is a written contract between an inventor and the government. The right to a patent monopoly originates solely from the laws of the United States, and, therefore, State laws cannot affect the benefits or advantages to be derived by the inventor, or the patent itself. Broadly speaking, any invention is patentable, irrespective of its simplicity, provided it is novel and useful and the inventive faculty is exercised in perfecting it. Whether a patented invention actually involves invention is determined by the important factor of whether the inventor has given the world something of value that it did not have, and the fact that the invention is a commercial success is greatly in its favor. And, further, that the determining factor, in deciding whether or not an invention is patentable, is not whether the achievement was difficult or easy.

Various attempts have been made to invalidate patents on the ground that the invention is so extremely simple that inventive faculty was not required to conceive it; but the Courts have held generally that the patentability of an invention cannot be determined by considering the task involved in perfecting or reducing the original idea to successful practice. Any advance in the art, however slight, if it produces the result by purely mechanical means, makes the device patentable. An improvement or device that produces a new and useful result or greater efficiency is the result of inven-

tion, even though after the invention was made, it would appear to many that anyone could have made it. The smallest difference in the structure of two inventions, which causes one to produce noticeably better results than the other, receives the benefit of the doubt when the validity of the patent is considered.

Many of the most valuable inventions comprise merely a combination of old and well-known elements. A patent on such a device is just as valid as if all the parts were new, because if by combining various old parts a machine is constructed by which new and useful results are accomplished, it lies in the class of patentable things.

While the general rule of the law is that infringement of a patent may be avoided by omitting an important element, yet a valid patent cannot be obtained on an old device by the omission of a part, unless the new invention is capable of producing new and useful results, or unless it operates in a different way.

For a patent to be valid, the patentee must have been the first one in the whole world to put the invention into practical usage; although there is one distinction, in that a simple use, without publication, in a foreign country will not bar an American inventor to a patent. However, many persons are under the impression that a valid patent need only relate to an invention that is new in the United States.

PATENT APPLICATIONS. The one who first conceives an invention is not under the law the first inventor, but the one who in addition to conceiving the invention, first reduces it to practice by making a working machine, device, or model, and shows it to others in order to substantiate his dates. The filing of an application for letters-patent is deemed to be a reduction to practice for the reason that the description and drawing must be so full and complete as to enable those skilled in the art to make and use the invention. However, the first person to file an application would not be given priority over an opponent who first conceived and made a demonstrable machine or device. If the one who first conceived an invention made a drawing of it which he signed and dated, and if the invention was explained to others, the dates of such disclosures being definitely known, or if the drawing was witnessed, then priority of inventorship doubtless could be established. If another inventor claimed the same invention, it would be necessary for him to submit proofs and testimony showing priority. Interference proceedings are of a complicated nature, and require experience and skill to a marked degree on the part of a patent attorney for their proper conduct.

Application Does not Afford Protection. — An application for letters-patent affords no protection whatever against any other party making and

selling the subject matter of the application. The application entitles the inventor only to notice of the filing of an application for a patent on a similar construction, in order that the question of inventorship may be determined by the Patent Office. Infringement can take place only from the day the patent is issued, and so anyone manufacturing the invention prior to the issuance of the patent would not be guilty of infringement.

A user of the invention would not be liable for such use prior to the issuance of the patent, but if the user were given notice of the existence of a patent which it was claimed he was infringing, and continued such use after notice, he would be liable, provided the validity of the patent was sustained by the Court after all proofs had been submitted. The Court will in all cases sustain a patent where it is possible to do so, but many of the patents that are litigated are so loosely written, or so poorly prosecuted before the Patent Office, that the Court is compelled to declare them invalid.

Application Prevents Grant to Another. — An application prevents the grant of a patent to another for the same invention at least until after an interference contest between two or more pending similar applications has been disposed of. For that reason, before commercially introducing a new invention, it is advisable to file a patent application therefor, to make certain that no patent will be issued on some other application simultaneously pending for the same invention. While it is true that patent litigation may develop whether this precaution is taken or not, nevertheless an interference proceeding is preferable to an infringement suit, for the reason that the former may result in patent protection, whereas the latter may result in an injunction and damages or loss of profits because of infringement.

Order of Examination. — Original applications for letters-patent are taken up for examination in the order of their filing, and no application will be given precedence over that of another, except in certain special instances. If the invention is deemed of particular importance to some branch of the public service, and if for that reason the head of a government department requests immediate action, and the Commissioner of Patents so orders, the case will be taken up out of its turn. Applications may also be advanced for examination by the Commissioner to expedite the business of the office, or upon a duly verified showing by the applicant that a delay will probably cause irreparable loss or injury. Orders to expedite the examination of applications on these latter grounds are rarely issued.

Abandoned Application. — An application is considered abandoned when the applicant has failed to prosecute it within one year after any action of which notice has been given. An abandoned application may be revived as a pending application when it can be shown to the satisfaction of the Commissioner of Patents that the delay was unavoidable.

Model Rarely Required. — A model is not required nor will it be admitted

as a part of an application, except when, on examination of the case by the primary examiner, it shall be found necessary or useful to a complete understanding of the invention. In such a case, the examiner will notify the applicant of the requirement. This will constitute an official action in the case, and further action will be delayed until the model has been supplied. The model must clearly exhibit every feature of the machine that forms the subject of a claim of invention, but should not include details not covered by the actual invention or improvement, unless they are necessary to the working of the model.

Patent Applied for in Name of Inventor. — Legally a patent may be "applied for" only in the name of the inventor. In other words, simply because an employer has the legal right, by contract or otherwise, to obtain title to the inventions of an employe is no reason why the employer may apply for and secure the patent in his own name. The law distinctly specifies that only the inventor may do this. While the employer may apply for and receive a patent for an article actually invented by another person, so long as the Patent Office officials are not informed of the true relation, if the employer does so, the patent is void and of no effect. Moreover, when an application for a patent is filed, the inventor must make oath that he believes himself to be the inventor of the thing to be patented.

PATENT ASSIGNMENTS. As to who may legally assign a patent, the answer is that only the real and true inventor may make a valid assignment. The assignment may be made when the application is filed, or at any time before or after the patent is issued. Also, it is important to know that the assignment of a patent must be in writing and recorded in the Patent Office within three months after the date of the assignment. If it is not recorded, a later creditor or purchaser may cause the original assignee trouble; but there is no regulation for recording merely an agreement to make a future assignment of a patent not yet issued. Sometimes an employer enters into a contract with an employe, by which the employe agrees to assign all inventions perfected during the employment.

PATENT MARKING. The law covering the marking of U. S. patents is as follows: "It shall be the duty of all patentees and their assigns and legal representatives, and of all persons making or vending any patented article for or under them, to give sufficient notice to the public that the same is patented; either by fixing thereon the word 'patent' together with the number of the patent or when, from the character of the article, this cannot be done, by fixing to it or the package wherein one or more of them is enclosed, a label containing the like notice. Provided, however, that with respect to any patent issued prior to April 1, 1927, it shall be sufficient to give such notice as in the following: 'Patented,' together

with the day and year the patent was granted; and in any suit for infringement by the party failing so to mark, no damages shall be recovered by the plaintiff except on proof that the defendant was duly notified of the infringement and continued, after such notice, to make, use or vend the article so patented."

Heretofore, the owners and assignees of all patents, and the makers of patented articles, were required by the law to mark patented articles with the word "Patented," together with the number of the patent or the day and year the patent was granted. However, with the new law in effect, a notice of "patented," with the date the patent was granted is insufficient, and an inventor thus marking his product is deprived of damages until after a notice is sent to the infringer notifying him of the number of the patent. In other words, the only notice that is legal on patented articles, the patents on which are granted after April 1, 1927, is: "Patent (patent number)." The word "patented" formerly used is replaced by the word "patent."

Inventors and manufacturers freely use the term "Patent Applied For" or "Patent Pending," believing an existing law supports its utilization; but there is no law in effect that authorizes its use; it is merely a term adopted by inventors themselves. There are many records of legal controversies, however, where persons who have used it to deceive the public have been prosecuted. An improper use of the phrase is looked upon by the Courts as a perpetrated fraud upon the public.

PATENT ON DESIGN. A design patent gives its inventor a monopoly to the exterior appearance of the thing patented. A design patent may be obtained by any person who has invented any new, original, and ornamental design for any article intended to be manufactured, but the interior views, or other parts that will not be seen when the apparatus actually is performing its service, cannot be protected. In the language of patent law, the word "design" does not mean the physical arrangement of the parts of a machine, but refers solely to its ornamental appearance.

Designs which Identify a Product. — The public may learn to recognize the "make" of a machine by the ornamental appearance of the design patented part; but in any event the housings or other portions that are designed partly to make the machine attractive, are of sufficient value to justify the expense of obtaining protection by means of a design patent. After the patent of a well-known product had expired, the design was adopted and used by another manufacturer. Legal proceedings were instituted against the latter user to prevent the adoption and use of the design, on the grounds that its appearance had become so well established in the minds of the public that the make of the machine on which it had

been used for so long a period was generally recognized by the design. But the Court held there was no recourse after the patent expired, even though the design was so well known to the majority of people that it indicated the name or make of the machine on which it had been used for so many years.

Patentable Design must be Attractive. — Occasionally a firm may be manufacturing a machine, the mechanical parts and principles of which are old and, therefore, unpatentable, but a design patent may be obtained on the new, ornamental and attractive appearance of the device or any part of it, irrespective of the fact that the mechanism is old, if the design is new.

Design Patents do not Protect Mechanical Principles. — A common source of litigation is where a design patent is obtained on a purely mechanical device which is made solely in consideration of the mechanical functions it is intended to perform. The law is well established that a design patent on a purely mechanical device is void and of no effect. Yet if the device is ornamental or attractive in shape, the mere fact that it performs mechanical functions is no reason why a valid design patent may not be obtained for it. For instance, a Court held a design patent infringed, and explained that the purpose of the design patent laws is to enable inventors to protect the exterior ornamental appearance of an article or device, and so long as it is formed to produce a desirable effect to the eye, the patent is valid, although the device is capable and intended to perform mechanical functions.

A design patent " must relate to an article that is pleasing to the eye, but it is immaterial that the subject may embody a mechanical device, if the appearance or design is pleasing, attractive, novel, useful, and the result of invention." Where a pitman or connecting-rod was formed with ordinary graceful curves merely to relieve the sharp corners, it was held not the subject of a valid design patent, because its shape was primarily intended to effect mechanical advantages.

PATENT RIGHTS. Considerable difficulty has arisen between employes and employers relative to the ownership of patents that are issued in the name of an employe without the knowledge of the employer. The holding of the United States Supreme Court is to the effect that if a patent is issued in the name of an inventor, and relates to an invention conceived, experimented with, and perfected on his employer's time, the true ownership of the patent lies with the employer. Of course, all these facts must be proved before a court will issue an order requesting the Patent Office to transfer the title of a patent already issued, from the name of the inventor to the employer.

Invention Made on Workman's Time. — Simply because an inventor is employed and paid to perform certain duties, the employer cannot, ordi-

narily, claim the ownership of an invention that an employe conceives and perfects while not engaged in performing his regular duty. In other words, an employer has no common law rights of ownership in an employe's invention which is made entirely on the employe's time, unless a contract to that effect exists or there is a written agreement between the employer and employe. Therefore the old custom of having contracts seems to be logical at present, the same as it was previous to the later court decision.

For many years it was customary to provide a written agreement between the employer and his workmen, wherein the employes specifically and unmistakably agreed to assign all the patent rights to the employer on inventions made while working on the employer's time. During those years the existence of such a contract was necessary in order to assure the employer that he would receive the benefits of the inventive faculty and ability of the employes, even though the inventors actually were paid to design and invent new things.

Contracts Which Protect Employer. — At present, a signed contract in which an employe unmistakably agrees to assign to his employer all inventions made on the employer's time, may eliminate litigation wherein the employer would be required to prove that the invention in controversy was perfected specifically in accordance with the present established law. Furthermore, an additional clause may be added to this contract in which the employe agrees to assign the patents on all inventions relating to kindred lines of business in which the employer is engaged, whether the inventions are conceived and invented on the employer's time or while the employe is in his own home, or elsewhere. The latter clause gives the employer important advantages, particularly for the reason that it may not be necessary for him to prove that the inventor actually did work on or perfected inventions on the employer's time, which is often very difficult to prove.

Protection of Both Inventor and Employer. — It is well to thoroughly understand that while the present law takes into due consideration the rights of an employer relative to the ownership of an invention made in his factory, even where no contract exists, nevertheless, the law also protects the inventor who may patent an invention conceived and perfected while he may be at his own home, or other places, during periods when he is not receiving remuneration from his employer. The law seeks to protect both the employer and the employe to the full extent of the rightfulness of the ownership of a patent.

PATENT ROYALTIES. See Royalties on Patents.

PATTERNS. A pattern of the type used in producing castings, is a model or form from which a mold can be made in damp sand or other suitable material. This mold when filled with molten metal gives the proper

shape to the required casting. The exterior form of an ordinary pattern corresponds to the shape of the casting to be produced, but if holes or interior passages are required in the casting, the pattern is provided with projecting core prints which will give it a different appearance from the casting which is reproduced in the mold. Materials for making patterns include wood, metal, and plaster.

One-piece Patterns. — The solid pattern is the simplest type. The term means that the pattern is in one piece, but it may be constructed of several pieces of wood which are fastened together permanently.

Parted or Split Patterns. — Most patterns are formed of two parts or sections which are kept in the proper relation to each other by dowel-pins or plates, and are known as *two-part patterns.* In making a mold from such a pattern, one-half of the pattern is first placed joint side down on the molding board so that, after the drag is "rammed up," this joint is flush with the parting line of the mold. The other half of the pattern is then placed in position, preparatory to ramming up the cope. The two-part construction enables the molder to locate the parting line accurately and with less work than is necessary when using a solid pattern. A *three-part pattern* is constructed for molding in a flask with three sections or parts.

Sectional Patterns. — It is often possible to make a part or section of a pattern which can be used by the molder, instead of supplying a complete pattern. This is common practice in making molds for circular work where but few castings are required. Rings of almost any section are frequently made by this method. The molder rams up a section of the mold and then moves the section of the pattern to the next position.

Skeleton Patterns. — Skeleton patterns are a framework the general outline of which conforms to that of the required casting. The spaces between the framework are filled by the molder with the molding material and are smoothed off to complete the pattern.

Shell Patterns. — Patterns of the shell type are used for making drainage fittings of all kinds. They are usually made of iron and are complete models of the finished casting.

Gated Patterns. — Gated patterns are small patterns fastened to the runners and gate pin to form a multiple pattern which can be used to mold a number of pieces at one time. The pattern-maker is sometimes required to make wood patterns on a gate, but more often he furnishes but a single pattern from which the molder casts the required number of patterns and then proceeds to mold and cast them on a gate. This gated metal pattern is then sent back to the shop to be finished smooth. See Draft on Patterns; Joints used in Patternmaking; Match-plate Patterns.

PATTERN SHRINKAGE ALLOWANCES. The shrinkage allowances ordinarily made on patterns to compensate for the contraction of castings

in cooling are as follows: Cast iron, from $\frac{3}{32}$ to $\frac{1}{8}$ inch per foot; common brass, $\frac{3}{16}$ inch per foot; yellow brass, $\frac{7}{32}$ inch per foot; bronze, $\frac{5}{32}$ inch per foot; aluminum, from $\frac{7}{32}$ to $\frac{1}{4}$ inch per foot; steel casting, $\frac{3}{16}$ inch per foot. The amount of shrinkage, in any case, depends to some extent upon the shape and size of the casting. A plain casting that is long in proportion to its width will contract differently from one that is more compact, even though both castings have the same weight and were cast from the same material. A heavy iron casting may shrink only $\frac{1}{10}$ inch per foot or even less, whereas a lighter casting of the same material may shrink $\frac{1}{8}$ inch per foot. A cylindrical or column-shaped casting will contract more in a length-wise direction than radially. Hence, when making patterns for rather large castings of this kind, the allowance should be about $\frac{1}{10}$ inch lengthwise and from $\frac{1}{20}$ to $\frac{1}{16}$ inch per foot radially. For pipes or other hollow castings, the lateral shrinkage is very much less than for solid castings or those having thick walls. A general rule for columns of comparatively small diameter but great length, such as are used for building purposes, is to allow $\frac{1}{8}$ inch per foot for shrinkage lengthwise and make no allowance on the diameter. The "one-tenth" shrinkage rule is the standard (for cast iron) in most machine pattern-shops. Although this is not the proper allowance for all forms of casting, the adoption of a standard eliminates the confusion that would follow the use of a number of rules for different classes of work. There can be no fixed rule governing shrinkage allowance, as it is largely a question of local conditions and practice.

PATTERNS, LACQUERING. Although it is general practice to apply several coats of shellac to wood patterns in order to keep out moisture and protect the glued joints, at least one prominent manufacturer has had very successful results in using lacquer instead of shellac. The advantages cited are that lacquered patterns draw from the sand much better, there is less tearing of the mold and smoother castings are obtained. Experiments have shown that the brushing lacquer is more satisfactory than a spraying lacquer, as the former fills rough places in the pattern more evenly. Wax fillets should be shellacked before applying lacquer, as otherwise the lacquer will not harden properly over the fillets and sticks to the molding sand. Metal plates and patterns which have not been sherardized may be protected from corrosion by the lacquer coating. The first cost of finishing a pattern with lacquer is greater than when shellac is used, but it is claimed a great many more castings can be obtained from a lacquer finished pattern than from a shellacked pattern before recoating is necessary.

PATTERNS, METAL. Metal patterns are especially adapted to molding machine practice, owing to their durability and superiority in retaining the required shape. The original master pattern is generally made of wood,

the casting obtained from the wood pattern being finished to make the metal pattern. The materials commonly used are brass, cast iron, aluminum and steel. Brass patterns should have a rather large percentage of tin, as this gives a good surface for the casting. Cast iron is generally used for patterns of large size, as it is cheaper than brass and more durable. Cast-iron patterns are largely used on molding machines. Aluminum patterns are light, but they shrink considerably. White metal is sometimes used when it is necessary to avoid shrinkage. The gates for the mold may be cast or made of sheet brass. Some patterns are made of vulcanized rubber, especially for light match-board work. In making master patterns of wood, two shrinkages must be allowed, and, in some cases, a double allowance for finishing. If the pattern is to be of iron for an iron casting, two cast-iron shrinkages must be allowed for, but if the pattern is to be cast iron and the casting of brass, one cast iron and one brass shrinkage will be necessary.

PATTERNS, RIGHT- AND LEFT-HAND. Many patterns are required in pairs, and when it is not possible to reverse them, and have the centers of hubs, bosses, etc., opposite and in line, they must be made right- and left-hand. If the pattern is a small one or if a great many castings are to be made from it, the better way would be to make two patterns, but if the pattern is large or if only one or two castings are required, the work should be laid out and planned so that the required pieces may be moved from side to side or from end to end in order to change the pattern from right- to left-hand.

PATTERNS, STANDARD COLORS. Standard colors for painting patterns, adopted by a joint committee on pattern equipment standardization consisting of official representatives from the American Foundrymen's Association affiliated with eight other national organizations are as follows: 1. Surfaces to be left unfinished are to be painted black; 2. Surfaces to be machined are to be painted red; 3. Seats of and for loose pieces are to be red stripes on a yellow background; 4. Core-prints and seats for loose core-prints are to be painted yellow; 5. Stop-offs are to be indicated by diagonal black stripes on a yellow base.

PATTERNS, VARNISH OR SHELLAC. A yellow or orange shellac varnish is generally used as a protective coating for pattern work, although there are other varnishes, such as copal, etc., that are used in special cases. Shellac comes in thin, flaky irregularly shaped pieces. It is brown in color and can only be cut with alcohol; grain alcohol is best, but wood or denatured alcohol is most frequently used, on account of the high cost of grain alcohol. Core prints and core outlines on the drag part of the pattern are colored,

and also surfaces concealed by loose pieces. There is no generally accepted standard for pattern coloring.

Black Shellac. — Black shellac is made by adding lampblack to orange shellac. The lampblack should be of good quality and free from grit.

Red Shellac. — A good grade of finely ground vermillion mixed with orange shellac may be used for making red shellac. All coloring matter should be ground dry.

Shellac dries quickly and is not easily affected by heat or moisture — two qualities which make it particularly desirable for finishing pattern work. It is also easy to cut through, which is another important consideration when patterns are to be altered. Pots for holding clear or yellow shellac should be of glass or earthenware, as the chemical action set up by the use of a metal pot will darken the shellac. See Patterns, Lacquering.

PATTERN WOOD. Woods commonly used for patterns are white pine, mahogany, cherry, maple, birch, white wood, and fir. For most patterns, white pine is considered superior because it is easily worked, readily takes glue and varnish, and is fairly durable. For medium- and small-sized patterns, especially if they are to be extensively used, a harder wood is preferable. Mahogany is often used for patterns of this class, although many prefer cherry. As mahogany has a close grain, it is not as susceptible to atmospheric changes as a wood of coarser grain. Mahogany is superior in this respect to cherry, but is more expensive. In selecting cherry, never use young timber. Maple and birch are employed quite extensively, especially for turned parts, as they take a good finish. White wood is sometimes substituted for pine, but it is inferior to the latter in being more susceptible to atmospheric changes. The Honduras mahogany or bay-wood is used for patternmaking, as it is much softer and easier to work than the mahogany used for making furniture, etc. Bay-wood is obtained near the Gulf of Campeche. It is worked almost as easily as pine and can be obtained in long and clear lengths, remarkably free from serious defects. The wood is of an open grain and requires careful finishing in order to obtain a smooth surface.

PEA COAL. Pea coal is small coal of such size that the pieces will not pass a screen of $\frac{1}{2}$-inch mesh, but pass a screen of $\frac{3}{4}$-inch mesh. Pea coal is often used for power plant purposes.

PEARLITE. Pearlite is a structural condition present in steel heated beyond the critical temperature and slowly cooled. If the steel that is thus slowly cooled contains very nearly 0.90 per cent of carbon, it will consist of pearlite alone. If it contains more than 0.90 per cent of carbon, it consists of pearlite and microscopic crystals of cementite, and if it contains less than 0.90 per cent of carbon, it consists of pearlite and microscopic

crystals of ferrite. Chemically, pearlite is composed of 86.5 per cent of ferrite and 13.5 per cent of cementite.

PEAT. Peat consists of decayed vegetable matter and earth, and is found in bogs and swamps. It is cut out and dried, and sometimes pulverized and compressed into blocks before burning. It gives an intense heat, burning with a short blue flame which changes to yellow when the grate spaces become filled with embers. One pound of air-dried peat contains about 7700 B.T.U. Peat briquettes have been used to some extent, and with fair success, in Northern Europe, both under stationary boilers and in locomotives, but, up to the present time, peat has not been employed commercially in the United States, for that purpose. It has been used successfully, however, to some extent in gas producers.

PEAUCELLIER MOTION. The exact straight-line motion invented by Peaucellier is composed of seven links moving about two fixed centers of motion. As this linkage swings about the fixed centers, the outer end follows a straight line.

PEENING METAL. When one side of a bar, rod, or plate is hammered, in order to expand or stretch the metal by indenting and compressing it, this is known as *peening*. The ball-peen hammer, which is the type commonly used by machinists, has a ball or spherical-shaped end that is adapted for peening or riveting operations. For peening some parts, the straight indentations left by the straight peen or cross-peen hammers are preferable to the spherical depressions formed by a ball-peen hammer. Peening is frequently done in order to straighten a shaft or bar by stretching the metal on the concave side. The extent to which the metal is expanded or stretched depends upon the area of the surface peened and the force of the peening blows. Some pumps have brass linings which are composed of staves or cast strips that are peened all over in order to secure a tight fit in the cylinder. The edges of these strips are first planed so that a fairly good fit is obtained before peening. After the peening operation, which not only tightens the strips but closes the lengthwise joints between them, the cylinder is bored. The inner sides of worn piston rings are sometimes peened in order to enlarge the ring and increase its bearing pressure against the cylinder wall.

PEENING PISTON RINGS. Concentric piston rings for internal combustion engines are peened on the inside by some manufacturers, in order to secure a ring which bears against the cylinder wall with practically a uniform pressure around the entire circumference, and a more durable and elastic ring, as the result of the hard compact surface formed on the inside by the peening process. This peening was formerly done by hand and was found to be a rather expensive item in the manufacture of the rings; more-

over, the peening was, in most cases, poorly done because of the difficulty in delivering blows of the required intensity when peening rings by hand, which resulted in a ring that did not have the desired resiliency or tension. Since the introduction of the automatic peening machine it is possible to peen rings mechanically and at the same time regulate the peening action.

PENDULUM. A *simple* pendulum is a material point which is supposed to be suspended from a fixed point by a string without weight. A *compound* pendulum is a material body suspended from a fixed axis about which it oscillates by the force of gravity. A *conical* pendulum is formed by a weight suspended by a cord and revolving at a uniform speed along the circumference of a circle in a horizontal plane. The application of the compound pendulum is found in all pendulum clocks. The principle of the conical pendulum is employed in the design of fly-ball governors.

PENDULUM HARDNESS TESTER. This is an instrument for testing the hardness of substances from lead to sapphires. It consists of a frame which is supported on the work by a ruby or steel ball, and may be oscillated like a pendulum. There is a curved spirit level at the top of the frame and a scale that permits of observing accurately the distance traveled by the bubble in the level when the frame oscillates. The hardness of a metal may be determined in two ways; first, by observing the distance that the bubble moves from the zero graduation on the scale with the first oscillation of the pendulum, and second, by ascertaining the length of time elapsed while the pendulum swings ten times. When placed to oscillate on plate glass, the bubble travels from 0 to 97 on the scale; in the first oscillation of the tester, however, on a less hard surface, such as on hardened steel, the ball will indent the surface slightly and elongate this indentation as the pendulum swings. The energy consumed in thus displacing the metal is taken from the potential energy of the pendulum, as is shown by shortening its first swing. The position of the bubble on the scale at the end of the first swing indicates the work done by the ball on the specimen, and is a measure of its hardness. In the case of a soft specimen, the indentation is relatively deep, and the pendulum comes to rest after a short swing; on lead it will not swing at all, so the bubble remains at zero. Typical scale-test readings with a steel ball are as follows: Glass, 97; very hard carbon steel, 93; hard carbon steel, 88; tempered high-speed steel, 75; annealed high-speed steel, 54; annealed carbon steel, 41; rolled brass, 14; cast brass, 4; and lead, 0. In making a time test, the hardness number is the time in seconds consumed in making ten single swings. The pendulum is placed gently on the specimen with the bubble at or near 50 and caused to oscillate through a small arc.

PENTABASIC ACID. In chemistry, this is an acid which has five atoms of hydrogen in each molecule replaceable by a metal.

PENTAGON. A pentagon is a plane figure or surface bounded by five straight lines. If the five lines are of equal length and the angles between the sides are equal, the figure is known as a *regular pentagon.* The angles between the sides of a regular pentagon are 108 degrees.

PENTAVALENT. Pentavalent, also known as quinquivalent, is a term used to indicate that an atom of one element will combine with five atoms of another element.

PERCENTAGE. The per cent of gain or loss is found by dividing the amount of gain or loss by the *original* number on which the percentage is to be based, and multiplying the quotient by 100. For example: Out of a total output of 280 castings a day, 30 castings are, on an average, rejected. What is the percentage of bad castings?

$$\frac{30}{280} \times 100 = 10.7 \text{ per cent.}$$

If by a new process 100 pieces can be made in the same time as 60 could formerly be made, what is the gain in output of the new process over the old, expressed in per cent?

Original number, 60; gain $100 - 60 = 40$. Hence,

$$\frac{40}{60} \times 100 = 66.7 \text{ per cent.}$$

Care should be taken always to use the *original* number, or the number of which the percentage is wanted, as the divisor in all percentage calculations. In the example just given, it is the percentage of gain over the old output 60 that is wanted, and not the percentage with relation to the new output 100. Mistakes are often made by overlooking this important point.

PERCH. One perch equals $16\frac{1}{2}$ feet, one rod or one pole. A perch of stone is $16\frac{1}{2}$ feet long, 1 foot high and $1\frac{1}{2}$ feet wide, and it contains $24\frac{3}{4}$ cubic feet.

PERCUSSION PRESS. A percussion press is a friction-driven type of press used for hot-pressing brass and steel parts and by jewelry and other metal goods manufacturers for work similar to that done with a drop-press. An important feature claimed for percussion presses is the cumulative blow delivered, all the energy of the flywheel being utilized as it comes to a dead stop. See Friction-driven Screw Press; Hot-pressed Brass Parts; Hot-pressed Steel Parts.

PERCUSSIVE ELECTRIC WELDING. Percussive electric welding differs from the Thomson or incandescent process in that the heating of the parts to be welded is done instantly by the sudden discharge of a heavy electric current from a condenser at the same moment as the two parts are forced together with a rapid blow. Hence, the resistance to the sudden rush of current momentarily melts the portions of the work that are to be joined at the very moment when they are suddenly forced together, so that a very intimate joint is formed. The process is applied mainly to the welding of wires of the same or dissimilar metals, and can also be used for the welding of a wire to an object of large dimensions.

PERFORATING DIES. The dies used for punching large numbers of holes or perforations in sheet metal, for producing strainers, sifting devices, etc., and also the dies used for cutting ornamental shapes around the edges of lamp-burner shells or galleries, etc., are commonly known as *perforating dies*. The type of die used for perforating sheet stock is, in reality, a multiple or gang die, but, as a general rule, the work of a perforating die differs from a gang die in that it is used to punch a large number of holes, whereas a gang or multiple die, as these names are ordinarily applied, means the type that is used to blank out a number of duplicate parts, punch rows of rivet holes, etc. There may be exceptions, however, to this general classification. Some perforating dies, such as are used for perforating sheet metal or other materials, have hundreds of punches which are arranged in rows and operate simultaneously.

PERFORATING PRESSES. Presses of this class are used for punching large numbers of small holes in sheet metal, for producing strainers, sieving devices, etc., and also for perforating the sides of circular parts, such as lamp-burner galleries, etc. The perforating of shells and flat sheets is done either in presses of ordinary construction fitted with special attachments or feeding mechanism, or by means of special perforating presses. For perforating heavy sheets or where the quantity required is so small that it is not economical to make a die covering the entire width of a sheet, a special type of press has been developed. This has a sliding table which automatically feeds the stock through the die. The latter may only have one punch or it may be equipped with a gang of punches, the type depending upon the design or quantity of perforating necessary.

PERIODIC LAW. In chemistry, this law is usually stated as follows: "The properties of the elements are periodic functions of their atomic weights." If the chemical elements are arranged in the order of their atomic weights, there will be found at regular intervals of the series, elements that have similar physical and chemical properties; that is, there is a periodic recurrence of similar properties. If these elements are arranged by

themselves in order, they form a group. The modern classification of the chemical elements is generally based upon these groups rather than upon the older methods of distinguishing between metals, metalloids, and non-metals.

PERIPHERY. The periphery is the curved line which forms the boundary line of a circle (circumference), ellipse, or similar figure.

PERMANENT HARDNESS. This is a condition in boiler feed water which is due to the presence in the water of sulphates, chlorides, and nitrates of lime and magnesia. As these are not precipitated until a temperature of 300 degrees F., or more, has been reached, water containing these impurities is known as permanently hard.

PERMANENT MOLD. This is a mold for making castings, which is made of metal and, hence, is of a comparatively permanent nature. A metal mold can be used for a large number of castings while a sand mold disintegrates for each casting made.

PERMEABILITY. Permeability may be defined as the conductivity of substances for magnetic lines of force. Air is taken as unity of permeability. The number of lines of force passing through different substances of the same length and cross-section is proportional to their respective permeabilities. The reciprocal of permeability is *reluctivity*. The permeability is sometimes, therefore, also defined as the reciprocal of the magnetic reluctivity. Any material which has a magnetic permeability greater than that of air is known as a *paramagnetic* substance, and any material which has a permeability less than that of air is known as a *diamagnetic* substance. The materials which are strongly paramagnetic, that is, have a permeability considerably greater than that of air, are iron, steel, nickel, and cobalt. The only material which is distinctly diamagnetic is bismuth. All other materials may be classed, generally, as non-magnetic. Their permeability differs from that of air by less than 1 per cent. Soft wrought iron is the most permeable of all materials known.

PERMEAMETER. The permeameter is an instrument for measuring the permeability of a piece of iron or steel with sufficient accuracy for commercial purposes, or for determining the mechanical properties of iron and steel by ascertaining the corresponding magnetic characteristics. In one form in which this instrument is built, the permeability is indicated by the magnitude of the mechanical force required to detach one end of the sample, arranged as the core of a straight electromagnet, from an iron yoke. The permeability is calculated when the value of this force is known. See also Magnetic-mechanical Analysis.

PERPETUAL MOTION. The numerous attempts to invent a machine capable of " perpetual motion " have failed because the successful operation of such a machine would require the creation of energy. According to the principle of work (neglecting frictional or other losses) the applied force, multiplied by the distance through which it moves, equals the resistance overcome, multiplied by the distance through which it is overcome. That is, a force acting through a given distance can be made to overcome a greater force acting as a resistance through a less distance; but no possible arrangement can be made to overcome a greater force through the same distance. The principle of work may also be stated as follows:

Work put into machine = lost work + work done by machine.

This principle holds absolutely true in every case. It applies equally to a simple lever, the most complex mechanism, or to a so-called " perpetual motion " machine. No machine can be made to perform work unless a somewhat greater amount — enough to make up for the losses — be applied by some external agent. As in the " perpetual motion " machine no such outside force is supposed to be applied, this problem is absolutely impossible, and against all the laws of mechanics.

PERSPECTIVE DRAWING. A perspective drawing may be defined as a representation upon a plane surface of the appearance of an object as seen by the eye from some given point of view. Perspective projection, therefore, differs from orthographic projection, as used in ordinary mechanical drawing, in that it represents the whole object in one view, showing its appearance as seen by the eye, but not showing the true relationship between the dimensions, nor showing the dimensions to any true scale. Oblique or isometric projection is also used, to some extent, to represent an object as it appears to the eye, but in these two latter types of projection the lines are drawn to some predetermined scale, so that an isometric or oblique projection may be said to form a step between the ordinary mechanical drawing and the true perspective.

PETROLEUM. Carbon and hydrogen in chemical combinations known as hydrocarbons form the main elements in petroleum and frequently there is in addition, relatively small amounts of oxygen, nitrogen and sulphur. The amount of carbon in crude oils usually varies from 80 to 89 per cent and the hydrogen from 10 to 15 per cent. The oxygen may vary from zero up to 5 per cent; the nitrogen from zero up to 1.8 per cent; and the sulphur, from 0.01 to 5 per cent.

Petroleum or " crude oil " is an inflammable mixture and is found in subterranean deposits which are tapped by drilling and may be located hundreds or even thousands of feet below the surface of the earth. There are three general classes of petroleum which may be defined respectively

as paraffin-base, which contains solid paraffin hydrocarbons and practically no asphalt; asphalt-base, containing asphalt and no paraffin; and paraffin-asphalt, which is a combination of these elements. The paraffin-base petroleum usually is of lightest gravity and yields the largest variety of lubricating oils. Although petroleum is sometimes used in the crude state for fuel or for surfacing roads and to lay dust on roads, the various motor fuel oils and lubricating oils, etc., are obtained by different distilling and refining processes.

The specific gravity of petroleum varies considerably according to its composition. It may be as low as 0.8 and as high as 1; frequently it is found to be about 0.88. Pure petroleum is composed mainly of hydrocarbons which distill at different temperatures. Some crude oils contain a large percentage of the lighter hydrocarbons, while others are composed principally of lubricating hydrocarbons.

The lightest vapors are driven off at about 115 degrees F., while the heavier vapors and oils require temperatures up to 600 degrees F. The heat value of petroleum varies with its specific gravity and also with the amount of impurities that it contains. California oil of a specific gravity of 0.92 has a heating value of about 19,000 B.T.U. per pound. Caucasian crude oil of a specific gravity of 0.88 has a heating value of 22,000 B.T.U. per pound. As a general average, the heating value of crude oil per pound may be assumed to be from 19,000 to 20,000 B.T.U.

PEWTER. The name "pewter" is given to a number of alloys of various metals in which tin is always the chief constituent. Generally, the alloy is composed of tin and lead. Thus, an alloy of 71.5 parts of tin and 27.8 parts of lead, or 78.2 parts of tin and 21.7 parts of lead, together with some impurities, is known as Roman pewter; but practically any composition of tin and lead, in which tin is the chief constituent, is known by the same name.

PHASE. The distance, usually in angular measure, of the base of any ordinate of an alternating wave from any chosen point on the time axis, is called the phase of this ordinate with respect to this point. The general term *polyphase* is applied to any system of more than a single phase. This term is ordinarily applied to symmetrical systems. *Single-phase* is a term characterizing a circuit energized by a single alternating e.m.f. Such a circuit is usually supplied through two wires. The currents in these two wires, counted positively outwards from the source, differ in phase by 180 degrees or a half-cycle. *Three-phase* is a term characterizing the combination of three circuits energized by alternating e.m.f.'s which differ in phase by one-third of a cycle; *i.e.*, 120 degrees. *Quarter-phase or two-phase* are terms characterizing the combination of two circuits energized by alter-

nating e.m.f.'s which differ in phase by a quarter of a cycle; *i.e.*, 90 degrees. *Six-phase* is a term characterizing the combination of six circuits energized by alternating e.m.f.'s which differ in phase by one-sixth of a cycle; *i.e.*, 60 degrees.

PHASE-ADVANCER. A phase-advancer, also called a "phase-modifier," is an asynchronous machine that supplies reactive volt-amperes for improving the power factor of an induction motor. Induction motors and other inductive apparatus take a component of current that lags behind the line pressure and thereby lowers the power factor of the system, while a noninductive load, such as incandescent lamps, takes only current in phase with the voltage and operates at unity or 100 per cent power factor. The operating conditions of an installed motor, which has turned out to be too weak, may be improved by a phase-advancer so that the motor is able to conform to heavier service than that for which it was originally designed. The compensating action of the phase-advancer is entirely automatic and it can be so designed that it corrects the power factor of the main motor from about one third to one and one-half the normal load, to unity or any other desired value, lagging or leading. The phase-advancer is only intended to be used in connection with induction motors that run continuously in one direction, and its most important application is with large slow-speed motors which have inherently a poor power factor, as well as to motors that run most of the time at part load and at a low power factor.

PHASE-CONVERTER. Phase-converter sets are used to counteract the difficulties encountered when single-phase loads are taken from polyphase systems; this often results not only in serious heating of the generators, but also in troublesome unbalancing of the voltage. The function of the converter is, therefore, to convert a single-phase load into a polyphase load, or, what is really the same thing, to absorb the unbalancing component of a power system with mixed load and redistribute it so as to give a resultant balanced polyphase load.

PHILADELPHIA CARRIAGE BOLT THREAD. This is a screw thread for carriage bolts which is somewhat similar to a square thread, but having rounded corners at the top and bottom. The sides of the thread are inclined to an inclusive angle of $3\frac{1}{2}$ degrees. The width of the thread at the top is 0.53 times the pitch.

PHONO-ELECTRIC WIRE. Phono-electric wire is a copper alloy wire which is intended primarily for railroad electrification and trolley work. This alloy may be produced in rod, sheet, or tube form; it is forgeable either hot or cold and can be cut much more readily than copper. When cold-drawn it has a tensile strength fully 50 per cent higher than hard-drawn copper and requires a much higher temperature to affect it adversely.

PHONOGRAPH. The phonograph was invented by Thomas A. Edison. The first demonstration of a practical working model was given in 1877, and the phonograph was patented in 1878. Originally the cylindrical record for recording and reproducing sounds was covered with a sheet of tin foil. Several years after the invention of the phonograph Dr. Alexander Graham Bell, inventor of the telephone, and his associates Messrs. Chichester A. Bell and Charles Sumner Tainter, directed their attention to the improvement of the phonograph; consequently in 1886 a patent was obtained covering the substitution of a wax surface for the tin foil sheet originally used. This invention was known as the "graphophone." The use of a flat disk instead of a wax cylinder was the distinguishing feature of the "gramophone," which was invented by E. Berliner and patented in 1887.

PHORAN. Phoran is the trade name of a material which is claimed to be capable of replacing diamonds in core drilling and stone cutting. This material is said to have a melting point of over 5400 degrees F., and consists of a mixture of tungsten carbide and tungsten. It does not soften or fuse at temperatures below the melting point, and possesses a hardness on the Moh scale between 9.8 and 9.9, the diamond on this scale having a hardness of 10.

PHOSPHOR-BRONZE. Copper is the chief element in phosphor-bronze; the other ingredients are tin and phosphorus with small percentages of zinc, iron, and lead. This metal is an excellent composition for use where anti-friction qualities are desired, standing up exceedingly well under heavy loads and severe usage. Phosphor-bronze resists corrosion to a considerable extent, and is, therefore, used for parts that are exposed to the action of salt water.

Phosphor-bronze according to S.A.E. specification No. 64 is composed as follows: Copper, 78.50 to 81.50 per cent; tin, 9.00 to 11.00 per cent; lead, 9.00 to 11.00 per cent; phosphorus, 0.05 to 0.25 per cent; zinc, maximum, 0.75 per cent; other impurities, maximum, 0.25 per cent. Good castings made of this alloy should give the following minima in physical characteristics: Ultimate strength, 25,000 pounds per square inch; yield point, 12,000 pounds per square inch; elongation in two inches or proportionate gage length, 8 per cent.

Phosphor gear-bronze according to S.A.E. specification No. 65 is composed as follows: Copper, 88 to 90 per cent; tin, 10 to 12 per cent; phosphorus, 0.10 to 0.30 per cent; lead, zinc and other impurities, maximum, 0.50 per cent. Good castings made of this alloy should give the following minima in physical characteristics: Ultimate strength, 35,000 pounds per square inch; yield point, 20,000 pounds per square inch; elongation in two inches by proportionate gage length, 10 per cent. This is a very

hard bronze and may be used for gears and worm-wheels subjected to severe service.

PHOSPHOR-COPPER. This is an alloy of phosphorus and copper containing up to 15 per cent of phosphorus, and used in the making of phosphor-bronze, the phosphorus being introduced into this bronze in the form of phosphor-copper.

PHOSPHOR GEAR-BRONZE. This is an alloy of copper and tin of the phosphor-bronze class. For S.A.E. specification No. 65, see Phosphor-bronze.

PHOSPHOR-TIN. This is an alloy of phosphorus and tin containing up to 5 per cent of phosphorus, and used in the making of phosphor-bronze, the phosphorus being introduced into this bronze in the form of phosphor-tin.

PHOSPHORUS. Phosphorus is one of the non-metallic chemical elements, the symbol of which is *P*, and the atomic weight, 31.04. Perfectly pure phosphorus is white and transparent, having the solidity of wax. It is usually, however, yellow in color, due to the presence of allotropic "red phosphorus." The specific gravity of phosphorus is about 1.82 at 32 degrees F. It melts at 44 degrees C. (111 degrees F.), when the specific gravity drops to 1.76. It boils at 290 degrees C. (554 degrees F.). Phosphorus is highly inflammable, taking fire in air at a temperature of 34 degrees C. (93 degrees F.). Its specific heat at 32 degrees F. is 0.202. So-called "red phosphorus" — an allotropic form of phosphorus — is produced by heating yellow phosphorus to about 300 degrees C. (about 570 degrees F.) in a closed vessel. Red phosphorus has a specific gravity of 2.25. It melts at about 610 degrees C. (about 1130 degrees F.). Its specific heat equals 0.183. Phosphorus enters as one of the impurities in a great many of the most important iron ores, and is nearly always present in commercial iron and steel. Its presence above a certain percentage is always detrimental to the quality of the steel, and various metallurgical processes are used for the purpose of reducing the phosphorus contents as much as possible.

PHOTOGRAPHS, PHANTOM. An illustration to show clearly some hidden interior part of a machine in relation to and more distinctly than other parts is usually obtained by first making a wash drawing from which a halftone is produced. This method is expensive, and the results are often unsatisfactory. The desired result may often be obtained by photography. Assume, for example, that in a power-driven machine, the power is transmitted through worm-gearing and a positive clutch, enclosed in an oil-tight case. An illustration showing the worm and worm-wheel in mesh is desired. The case and its contents are removed from the machine and mounted on a box. The upper part of the case is taken off, leaving

the worm-wheel and the clutch collar exposed to view. The worm and shaft are removed from the upper part of the case and placed in their proper position in relation to the worm-wheel. A dark background is placed in the rear and an exposure is made. After the exposure, the cap is put on the lens, the worm and shaft taken away, and the upper part of the case put in position. A light background is substituted for the dark one, and another exposure is made on the same plate.

PHOTOMICROGRAPHY. Photomicrography is the science of photography under high-power microscopes. With a photomicrograph a piece of steel has been enlarged and photographed 15,500 diameters in a single projection. Such magnification is so tremendous that only objects invisible to the naked eye can be dealt with in order to be able to get the enlarged image on a photographic plate. This same combination of lenses is capable of separating and photographing lines lying so close together that 200,000 of them are contained within a single inch. The apparatus used in carrying out this work, a Leitz micro-metallograph, consists essentially of a very high power microscope arranged between a powerful automatic arc light and an extremely fine camera, the entire apparatus being mounted on a carriage suspended on sensitive springs so that even a slight movement of the floor will not disturb it. See Metallography.

PHOTOSTAT. The apparatus known as a "photostat" consists of a camera having, in addition to a lens, a prism which prevents the part photographed from being reversed on the copy. A light-tight magazine holds a roll of sensitized paper, and a mechanical device is provided for unrolling and cutting off the paper to the required length. The photostat provides a rapid and inexpensive method of making reproductions of drawings, blueprints, catalogue pages, maps, and, in fact, any flat copy that can be photographed. The reproductions (also called "photostats") generally are negatives, but positives can be made by a second photographing. One of the important uses of the photostat in manufacturing plants is in copying blueprints, when the original drawing is not available, as is often the case when customers send blueprints, or when old record prints of early designs of machines are to be used for making repairs. With the photostat, the copies are reversed in color, that is, where the original is dark the copy becomes light, and *vice versa*. Copies of blueprints have dark lines on a light background, thus giving the effect of an original drawing.

PI (π). The Greek letter π is used to denote the ratio of the circumference of a circle to its diameter; hence, it is a number constant for all circles. It cannot, however, be expressed by an exact arithmetical figure, because it is an incommensurable number — that is, a number having

an infinite number of decimals. The ratio has been calculated to as many as 707 decimals; this was done by Shanks, in 1873. The first twenty-five decimals are as follows:

$$3.1415926535897932384626434.$$

For practical use, the first four decimals only are required. As the fifth decimal is "9," the fourth decimal is raised to "6" when only four decimals are used; hence, π, for ordinary calculations, is almost always assumed to equal 3.1416. Fractional approximations that give very close results are to assume π equal to 22/7 or 355/113.

PIANO WIRE. Piano wire, also known as *music wire*, is a high grade of steel wire. It has an ultimate strength of from 300,000 to 340,000 pounds per square inch, the wire being drawn in comparatively small sizes only.

PICKLING CASTINGS. Castings are "pickled" or immersed in an acid bath in order to soften and remove the sand and scale on the surface of the castings, so as to make it easier to machine them and reduce the wear of tools and the time required for their resharpening and resetting. The pickling solutions used for removing scale from castings and forgings preparatory to milling or other machining operations are usually composed either of dilute sulphuric acid, oil of vitriol, or hydrofluoric acid. Iron castings are usually pickled with sulphuric acid. The sulphuric acid pickling solution is generally made up of one part of sulphuric acid to from four to ten parts of water. The sulphuric acid should always be poured into the water while the latter is being stirred. The reason for this is that a chemical reaction takes place which causes the bath to become quite warm, but there is no dangerous ebullition if properly mixed. However, if the water is poured upon the sulphuric acid, the latter, being much heavier than water, remains at the bottom. When an attempt is made to stir the solution, the water enters the acid in small streams, and is instantly raised to the boiling point, generating steam, which may cause an explosion.

PICRIC ACID. Picric acid, chemically, is similar to nitroglycerine, in that it is a trinitro-phenol, whereas nitroglycerine is a trinitro-glycerine. Picric acid is a powerful explosive with a very high melting point; so high, in fact, that it must be adulterated to bring its melting point down in order to make it of practical value. It is one of the most dangerous explosives to handle or manufacture. Phenol, from which picric acid is made, is the chemical name for what is commonly known as carbolic acid.

PICUL. This is a Chinese capacity measure, legalized in 1908, equal to 103.55 liters or 27.36 gallons.

PIECE-WORK WAGE SYSTEM. The piece-work plan of paying wages is based upon the principle of paying the workman for the exact amount of work produced. See Wage System, Piece-work.

PIEZOMETER. The piezometer is an instrument of meter used for determining the pressure in a pipe containing water or other fluid. It consists simply of a vertical tube inserted into a pipe containing fluid under pressure. The fluid will then rise in the tube, and the vertical height to which it rises will be equal to the head producing the pressure at the point where the tube is inserted. The instrument is sometimes used for determining the location of obstructions in pipe mains. If the observed pressure at any one point falls below what would be expected under normal conditions, there is an obstruction between this point and the water reservoir. If the pressure recorded by the piezometer is higher than normal, it shows that the pressure at this point has been increased by an obstruction beyond the point where the instrument is located.

PIG IRON. Pig iron, which is a product of the blast furnace, is obtained directly from iron ore, and is the raw material used in the production of all kinds of iron and steel. The term "pig" is derived from the original method of casting the bars of pig iron in depressions or molds formed in a sand floor adjacent to the blast furnace. The molds in the pig bed were connected to a runner or feeder (known as the "sow"), and, when filled with metal, this runner and the numerous smaller molds were supposed to resemble a litter of sucking pigs; hence the name "pig iron." What is known as *sand cast pig* is produced in this way. *Chill cast pig* is made in metal molds or chills, and *machine cast pig*, in a pig-casting machine. Pig iron is remelted usually in a cupola, for making ordinary castings, and it is converted into steel either by the open-hearth, Bessemer, or crucible processes, and into wrought iron, by the puddling process. Pig iron contains about 93 per cent of pure iron, from 3 to 5 per cent of carbon, and some silicon, manganese, sulphur, and phosphorus.

Grades of Pig Iron. — Pig iron may be classified either according to its composition, its intended use, or the method of manufacture. The modern method of grading pig iron is by chemical analysis. The former practice was to examine the fracture of a broken pig. If the silicon is low and the carbon all combined, the fracture is white, whereas, if the silicon is high, the fracture is silvery. If the carbon is in the form of graphite, the fracture is gray. Terms such as "high silicon pig," "low phosphorus pig," etc., are used to indicate an important element in the composition. Pig iron may be classified according to the methods of manufacture, as, for instance, *coke pig*, which is smelted with coke; *charcoal pig*, which is smelted with charcoal; and *anthracite pig*, which is smelted with anthracite coal mixed

with coke. The name given a brand or grade of pig iron may also indicate its intended use. For instance, *Bessemer pig* is used for making acid Bessemer and acid open-hearth steel; *basic pig* is used for the basic open-heart process; *foundry pig*, for general foundry work; *malleable pig*, for making malleable cast-iron castings. The names " iron " and " pig " are often used as abbreviations for pig iron.

PILLAR CRANE. This is a crane consisting of a column or post supported and pivoted at the foundation, a boom extending from a point near the foundation to the point where the tackle for lifting the load is mounted, and a tie rod which connects this latter point with the top of the column or post. There is no trolley moving horizontally along the arm as in a jib crane, and the load, therefore, is moved in a horizontal direction along the periphery of a circle only, but has no radial movement. The type known as " pillar jib crane," however, is provided with a jib on which a trolley moves, so that the load can be moved both in a radial and circular direction.

PILLAR FILE. This is a style of file that is parallel as to width, but tapers somewhat in thickness toward the point. The cross-section of a pillar file is similar to that of a hand file, except that it is thicker in proportion to the width; these files are made in narrow and extra narrow patterns. They are double-cut and are applicable to general machine shop work, especially in connection with erecting and fitting.

PILOT FOR CUTTING TOOLS. A pilot for metal-cutting tools such as boring-bars and reamers, is a cylindrical part which extends beyond the cutting end and enters a close-fitting hole in some rigid member, thus supporting the cutting edges and preventing the lateral deflection that might otherwise occur.

PILOTS FOR PUNCHES. Pilots or guide pins are placed on the ends of some punches for aligning the stock before blanking, by entering holes that have been pierced previously. A pilot should be made slightly smaller than the hole in the blank and should be straight for the thickness of the stock, and then rounded off similar to the point of an acorn. When pierced holes are very small the punch should be provided with a spring pilot, so that if the pilot misses the pierced hole in the blank, it will spring back into the punch.

PINION BLANK ENLARGEMENT. When an ordinary pinion is used (having a pressure angle of $14\frac{1}{2}$ degrees) twelve teeth is generally considered the minimum number if the addendum conforms to the usual standard. Even with a pinion of this size, the flanks of the teeth must be under-cut somewhat to avoid interference, provided the mating gear has more than

twelve teeth, and this interference and the need for under-cutting increases if the pinion is to run with larger gears. A method of improving the shape of the pinion tooth that has long been employed consists in enlarging the pinion blank and reducing the gear blank a corresponding amount. Another method is to increase the pressure angle of the gearing, and a third method consists in modifying both the pressure angle and the blank diameters in order to obtain a tooth shape giving the best results. Enlarging the pinion blank and decreasing the gear blank a corresponding amount (if the center distance is to remain the same) is applied not only to spur gears but also to bevel gears, worm-gearing, and herring-bone gears. In cutting an enlarged pinion or a reduced gear (whether by hobbing or on a generating shaper or planer) the procedure is the same as for cutting standard gear teeth, and any generating type of machine may be used. The teeth are cut to the full depth on both pinion and gear, and in the usual manner, but if the position of the cutter relative to the gear blank is checked by measuring the tooth thickness, then the change in the height of the pinion and gear addendum must be taken into account the tooth thickness being measured where the pitch circle crosses the tooth in each case. When the pinion blank is enlarged and the gear blank reduced, without changing the pressure angle, the practical effect is to move the pinion teeth outward radially and the gear teeth inward a corresponding amount relative to the pitch circles as well as to the base circles from which the tooth curves are derived.

PINION ROD. Many small steel and brass pinions are produced by first making the pinion in rod form, and then cutting the rod into whatever lengths are required for the pinions. The teeth are formed along the rod, which may have a length of three or four feet. The companies making pinion rod usually sell it in rod form, and the manufacturer using the rod cuts it into short pinion lengths. Either a hand screw machine or an automatic is generally used for this purpose, the machine being employed to cut whatever shoulders, holes, or bearing surfaces are required for the pinion. *Cold-drawn pinion rod* is produced by methods that, in a general way, are practically the same as the methods employed for making cold-drawn rods or other sections. Care has to be exercised in determining the various reductions and annealings, in order to obtain the correct shape of tooth and size of rod, as well as the most suitable temper in the finished rod, for obtaining good cutting qualities.

PINIONS, LANTERN. See Lantern Pinions.

PINTLE CHAIN. What is known as a " closed end " pintle chain was designed primarily to replace link-belts of corresponding pitch for transmissions requiring greater strength, or where the amount of dirt or grit was such as to interfere with the operation of the " open-hook " connection

of the link-belt. This "closed end" chain is adapted for elevating or conveying machinery, or for power transmission.

PIPE. Pipes are manufactured from various metals such as cast iron, wrought iron, steel, brass, copper, and lead. Cast-iron pipes have no flexibility but they are cheap and have the required strength, especially for such purposes as gas and water piping. The pipes can be provided with flanges which are readily faced in a lathe, and they can be cast to any convenient length. For general purposes, and for pressures up to about 100 pounds per square inch, cast-iron piping is likely to always occupy an important place. Many engineers consider that cast-iron pipes should not be used for pressures above 120 pounds per square inch in steam piping or in cases where a leak or bursting would cause serious damage. Wrought-iron and steel pipes are, therefore, used for higher pressures. Small pipes up to 2- or 3-inch sizes may be made of plates or skelp by butt welding; larger sizes are lap welded. The butt-welded pipe has about 80 per cent of the strength of lap-welded pipe. The steel for piping should be of a low-carbon quality similar to boiler plate, with a tensile strength of from 55,000 to 60,000 pounds per square inch, and an elongation of not less than 20 per cent in a length of 8 inches. The flanges of steel and wrought-iron pipe are attached by three methods: Riveting, welding, and threading.

Copper pipes are used mainly for steam piping, but the use of copper piping is not as common at the present time as it was some years ago. Copper pipes are flexible, but do not have the strength obtainable with steel or wrought-iron pipes, and the strength is rapidly reduced at high temperatures. At a temperature of 360 degrees F., for example, the strength of copper is reduced 15 per cent. Copper, therefore, must be employed with caution for high pressures, and is not a suitable pipe material for conveying superheated steam.

Pipe is ordinarily furnished in 16-foot lengths, each length being threaded at each end. Short pieces of pipe threaded at both ends are known as *nipples*. If the piece is so short that the threads cover the whole outside, it is called a *close nipple*.

Wrought-iron and Steel Pipe. — Wrought-iron and steel pipes are made in three different thicknesses, known as *standard*, *extra strong*, and *double extra strong*. The actual outside diameter is the same, the increased thickness of the wall merely decreasing the internal diameter. The term "wrought-iron pipe" is often used indiscriminately to designate all butt- or lap-welded pipe whether made from wrought iron or steel, but the term *wrought pipe* is preferable for designating either steel or wrought-iron pipe. A large percentage of the wrought pipe now used is made of steel. When wrought-iron pipe is desired the term "genuine wrought iron" or "guar-

anteed wrought iron " should be used, as otherwise the manufacturer will invariably supply steel pipe.

The size of iron and steel piping is specified in terms of the nominal inside diameter excepting for the large sizes, as noted later. For standard pipe, the actual inside diameter is usually greater than the nominal, especially on the smaller sizes, but in the extra strong, and especially in the double extra strong pipe, the internal diameter is less than the nominal size. The thickness of the wall and the weight per linear foot of piping varies on account of the difficulty in securing uniformity in the process of manufacture. It is assumed to be permissible for standard weight pipe to vary from 5 per cent above to 5 per cent below the standard weight. A class of pipe known as *merchant* pipe, which is ordinarily carried by jobbers, is almost invariably from 5 to 10 per cent under the nominal weight. In specifying pipe, therefore, it should be stated whether " merchant," full weight, extra strong, or double extra strong pipe is required.

Formerly wrought iron was preferred for the best classes of work, but records of installations and tests have demonstrated that steel pipe is equal to wrought-iron pipe for general work and, according to some authorities, resists corrosion, in the average case, as well as wrought iron; the steel pipe is also cheaper than wrought iron, and according to one estimate 90 per cent of the wrought pipe made in the United States is of steel. The term *galvanized iron pipe* is applied to ordinary wrought pipe which has been galvanized. The abbreviated expression *O. D. pipe*, which is found in manufacturers' catalogues, is applied to large wrought pipe, the nominal size of which is designated by the outside diameter instead of the inside diameter as in the case of smaller sizes. It is common practice to designate the nominal sizes of all pipes above 12 inches by giving the outside diameter, although this is not an invariable rule. The National Tube Co. designates all pipes above 15 inches inside diameter, by the outside diameter. The nominal sizes of boiler tubes also indicate the outside diameter.

Cast-iron Pipe. — Cast-iron pipe is used instead of wrought pipe where the pipes must be placed under ground or submerged, and also for main steam pipes and branches which are subjected to acids. Cast-iron pipe is extensively employed for cold water on lines 4 inches in diameter and above. Commercial cast-iron pipe is unsuitable for lines subjected to expansion strains, contraction, and vibration unless the pipe is very heavy. It is not suitable for superheated steam or for temperatures above 575 degrees F. The cast-iron pipe used for underground work generally has the *bell-and-spigot* ends which are leaded and calked to secure a tight joint. Exposed cast-iron pipes usually have flanged ends. According to the specifications issued by the American Gas Institute, all cast-iron pipe used for gas piping should be subjected to a water pressure test of at least 300 pounds per square

inch, for pipe 16 inches in diameter and smaller, and at least 150 pounds per square inch for pipe 20 inches in diameter and larger.

PIPE BENDING. In bending a pipe or tube, the outer part of the bend is stretched and the inner section compressed, and as the result of opposite and unequal stresses, the pipe or tube tends to flatten or collapse. To prevent such distortion, the common practice is to support the wall of the pipe or tube in some manner during the bending operation. This support may be in the form of a filling material that is placed inside the pipe, or it may be external only and consist in using a bending device provided with curved or concave forms or rolls that prevent collapse in making the bend. For certain classes of pipe and tube bending, some form of internal mandrel is used so that the pipe or tube is supported both externally and internally in order to prevent flattening. Internal mandrels are used particularly in connection with the bending of thin tubing. The mandrel may be in the form of a plain cylindrical bar that fits closely inside the tube, or it may be of special form.

The equipment used for bending may be merely a simple hand-operated fixture or a power-driven pipe-bending machine, the apparatus used depending upon the size of the work and the amount of bending to be done. Some of the bending fixtures are special and intended for making a certain bend or combination of bends in duplicate pipes, whereas other fixtures are designed for general application.

Filling Material to Prevent Flattening. — A simple method of preventing distortion and one that has been widely utilized, especially when pipe or tube bending is done by hand and without a bending fixture, consists in using some filling material which is placed inside the pipe to support the walls to prevent flattening at the bend. Dry sand is often used for this purpose. The sand should be rammed tightly into the pipe to fill it completely, and then the ends should be capped so that all the sand will be retained. The section to be bent is next heated, care being taken to avoid overheating. Before bending, the outer surface is cooled by using water, so that the inner wall will be compressed; this causes the cubic contents of the pipe to be reduced slightly by the bending, whereas, if the outer portion were not cooled and were permitted to stretch, the space within the pipe would be increased somewhat. The cooling method, therefore, enables the filling material to provide a firmer support.

Other filling materials, such as rosin or lead, are sometimes employed. The pipe is first filled either with molten rosin, lead, or some alloy having a low melting point, and then after bending, the pipe is heated sufficiently to melt the filling material. Rosin has often been used for bending small brass and copper pipes, and lead or some alloy for small iron and steel pipes.

Before bending either copper or brass pipe or tubing, the latter should be annealed. A snugly fitting coil spring has been used instead of one of the filling materials mentioned. One method of removing the spring after bending is to fasten one end of the spring to a lathe spindle, which is then rotated so as to wind the spring in whatever direction will reduce its diameter. The spring should be lubricated before using.

Location of Seam Relative to Bend. — The general practice in bending butt-welded pipe is to have the seam at the side of the bend. This is based on the assumption that in making a bend, the neutral axis is midway between the inner and outer curves, and therefore this part of the pipe is not subjected to extension or compression while bending. If the method of bending or the equipment used conforms to the assumption referred to, then the foregoing rule is correct; but in actual practice there is more or less deviation, depending on the type of equipment and the nature of heating. For example, it has been found in some experiments in making hot bends according to the best practice, that curvature is more the result of compressing the material on the inside than stretching it along the outer curve. In such cases, the neutral axis would lie somewhat outside the center line. One manufacturer, who has been very successful in making bends, lets a stream of water flow over the outer curve, while making a hot bend, so that practically the entire bend is obtained by compressing the material. This is considered good practice, since there is a minimum stretching and thinning of the pipe wall. When this method is employed, the seam should be along the outer curve because in any other position there would be a tendency toward buckling or shearing stresses which might result in splitting.

PIPE BEND LENGTH ALLOWANCE. In determining the required length of a pipe or tube before bending, the lengths of the straight sections are, of course, added to the lengths of the curved sections in order to make the proper allowance for bends. The following rules may be used for finding the lengths of the curved sections.

Rule: To find the length of a 90-degree or right-angle bend, multiply the radius of the bend by 1.57 (the radius is measured to the center of the pipe or to a point midway between the inner and outer walls).

Rule: To find the length of a 180-degree or U bend, multiply the radius of the bend by 3.14.

Example: A right-angle or 90-degree bend is to have a radius of 10 inches and straight sections on each side of the bend of 5 and 15 inches, respectively. Find the total length of the pipe before bending.

Length of curved part $= 1.57 \times 10 = 15.7$ inches; hence total length $= 15.7 + 5 + 15 = 35.7$ inches.

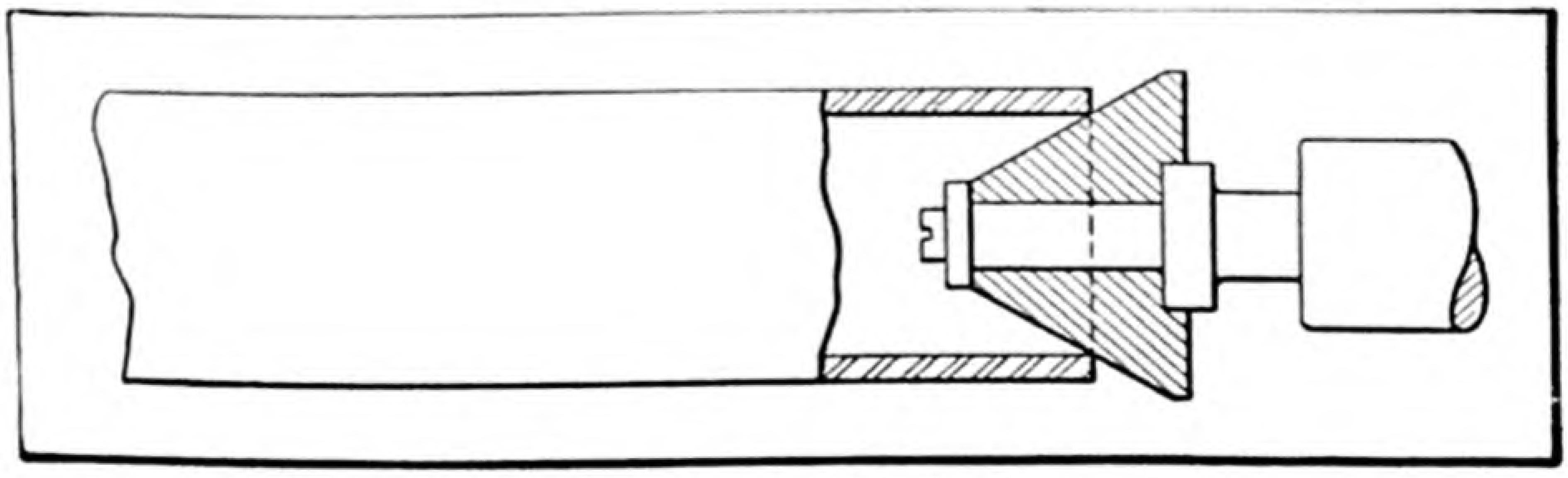
A general rule for finding the lengths of sections having degrees of curva-

ture other than 90 and 180 is as follows: Multiply the radius of the bend by the included angle, and then multiply the product by the constant 0.01745. The result is the length of the curved section. To prevent flattening at the ends there should be a straight section adjoining the bend equal at least to the pipe diameter or to $1\frac{1}{2}$ times the diameter for pipes larger than 10 inches.

PIPE BEND RADIUS. Pipes are often bent to avoid the use of fittings, thus eliminating joints, providing a smooth unobstructed passage for fluids, and resulting in certain other advantages. Sometimes it is desirable to make the radius of the bend as small as possible without causing distortion, whereas on other classes of work, the radius may be comparatively large, as, for example, when pipes are curved to provide means of compensating for expansion and contraction in a line of piping. The safe minimum radius for a given diameter, material, and method of bending depends upon the thickness of the pipe wall, it being possible, for example, to bend extra heavy pipe to a smaller radius than pipe of standard weight. As a general rule, wrought iron or steel pipe of standard weight may readily be bent to a radius equal to five or six times the nominal pipe diameter. The minimum radius for standard weight pipe should, as a rule, be three and one-half to four times the diameter. It will be understood, however, that the minimum radius may vary considerably, depending upon the type of fixture or machine used for bending. Extra heavy pipe may be bent to radii varying from two and one-half times the diameter for smaller sizes to three and one-half to four times the diameter for larger sizes.

PIPE, BUTT-WELDED. See Butt-welded Pipe.

PIPE CENTER. This is a conical center (see illustration) often used for holding one end of a pipe or tube when turning the outside surface in a



Pipe Center for Lathe

lathe. The conical member is free to rotate on the shank which fits into the tailstock spindle and is adjusted with reference to the work the same as an ordinary center. A center of this type is used for holding parts

having holes that would be too large for an ordinary center. The opposite end of the work is usually held in a chuck.

PIPE CENTER REAMER. This is a conical reamer used for reaming the ends of large holes — usually cored — so that they will fit upon a center in a lathe. The cutting part of these reamers is generally in the shape of a frustum of a cone.

PIPE COLUMN. This is a strut or column made from ordinary commercial pipe. No pipe column should be used having an unsupported length greater than 120 times its radius of gyration.

PIPE COVERINGS. Steam and feed-water pipes are protected with heat-insulating coverings in order to prevent loss of heat by radiation. Under ordinary conditions, about 3 British thermal units per square foot per hour, per degree difference in temperature, are radiated from a bare pipe. The best commercial heat-insulating materials used for pipe covering will save from 75 to 85 per cent of this loss. Among the various materials used for covering pipe may be mentioned hair felt, cork, magnesia, and mineral wool. Asbestos is a very poor non-conductor of heat, but it may be used to advantage as a binder in other insulating substances. A common covering consists of 85 per cent carbonate of magnesia mixed with 15 per cent of asbestos. The covering should be at least 1 inch thick and preferably from 2 to 3 inches, depending on the size of the pipe. It is generally manufactured in sections molded in halves to fit the pipe. Valves and fittings may be covered with the same material in a plastic state. The covering is secured in place by means of heavy duck or canvas and bands made of brass or sheet iron placed at regular intervals along the pipes. Many commercial pipe coverings are made from two or more of these substances. Pipe laid in trenches may be insulated by the use of ashes, coke, loam, or charcoal.

The actual heat losses in a steam pipe depend upon the size of the pipe, its position, the nature of the pipe surface, and the velocity of the air surrounding the pipe. Horizontal steam pipes radiate heat more rapidly than vertical pipes, the reason for this being that the heated air surrounding a vertical pipe travels upward along the surface of the pipe, while with horizontal pipes the heated air rises immediately upon being heated, thus making room for cooler air, which is, in turn, heated. For all practical purposes, however, it is customary to assume a loss of 3 B.T.U. per square foot, per hour, for each degree F. difference in temperature between the steam in a bare steam pipe and the air surrounding the pipe. Tests made on an 8-inch standard steam pipe 60 feet long, carrying steam at from 109 to 117 pounds per square inch gage pressure, and surrounded by air at temperatures varying from 58 to 81 degrees F.. showed that each square

foot of bare pipe surface radiates approximately 2.706 B.T.U. per hour, per degree average difference of temperature between the steam in the pipe and the outside air.

PIPE DISCHARGING CAPACITY. There are many formulas for calculating the discharge of water through a pipe; some of them are quite complicated, and all are, and must of necessity be, approximate. It is impossible to derive one formula that will fit every case. The pipe, or conduit, is made of various materials, and the friction of the moving water varies greatly with the material of which the pipe is composed. Even for a particular material, the discharge will not be the same for a pipe that has been in use a long while as for a new pipe. The impurities carried by the water stick to the pipe, causing it to become foul; this reduces the diameter and discharge, and also alters the resistance due to friction. If the slope is not gradual and even, air will accumulate at different points; this also reduces the discharge, since the area of the cross-section at those points is less. Bends, especially those of short radius, reduce the velocity and, consequently, the discharge. Contractions and enlargements, likewise, exert a deterrent effect.

As a result of the examination and comparison of a large number of experiments, the following formula has been derived; it is simple in form, is said to give good results, and is adapted to logarithmic computation: $v = 0.0757cd^{\frac{2}{3}}\left(\frac{h}{l}\right)^{\frac{1}{2}}$, in which v = velocity, in feet per second; d = diameter of pipe, in inches; h = head, in feet; l = length of pipe, in feet; and c = a constant the value of which depends on the material of which the pipe is composed. For new, smooth, wrought-iron pipe, laid straight and without bends, c may be taken as 160. Since the actual internal diameter of a $1\frac{1}{2}$-inch pipe is 1.61 inch, the velocity of discharge in the pipe is $v = 0.0757 \times 160 \times 1.61^{\frac{2}{3}} \times \left(\frac{60}{2640}\right)^{\frac{1}{2}} = 2.508$ feet per second. The number of cubic feet per minute discharged is $\frac{60 \times 2.508 \times 0.7854 \times 1.61^2}{144}$ $= 2.127$; $2.127 \times 7.48 = 16$ gallons per minute.

PIPE FITTINGS OF FLANGED TYPE. Flanged joints are the standard form of connection for many classes of piping. For most purposes, the ordinary screw connection should not be used for pipe sizes over 6 inches, on account of the difficulty of making and breaking joints. The American Society of Mechanical Engineers and the Master Steam and Hot Water Fitters Association, assisted by the manufacturers of fittings, adopted a standard which covered flange dimensions and bolting only, and which was known as the A. S. M. E. Standard of 1894. A few years later, the

manufacturers realized that there was need for a standard of extra-heavy 250-pound flanges and bolting, and the Manufacturers' Standard of 1901 was adopted. In order to standardize the center-to-face and face-to-face dimensions of all flange fittings, the American Society of Mechanical Engineers and the Master Steam and Hot Water Fitters Association adopted another standard known as the 1912 U. S. Standard. This standard, however, differed, in some respects, from the dimensions which had been quite generally used by manufacturers, and at a meeting held in New York City in July, 1912, a standard known as the Manufacturers' Standard was adopted by the pipe fitting manufacturers. In order to avoid the confusion of having two standards in the field, an effort was made to bring about a compromise of the differences between these two standards, and this compromise, which became effective January 1, 1915, is known as the "American Standard." "The 1915 U. S. Standard," which name was adopted by the National Association of Master Steam and Hot Water Fitters, is the same as the American Standard. Three standards for hydraulic fittings have been adopted by the American Society of Mechanical Engineers. These are known, respectively, as the 800-pound, the 1200-pound, and the 3000-pound Hydraulic American Standard. The dimensions of flanged fittings will be found in engineering handbooks.

PIPE FITTINGS OF THREADED TYPE. Screwed pipe fittings for use with "wrought pipe" are usually made of cast iron or malleable iron but they may also be made of either cast or forged steel for exceptionally high-pressure service. There are different weights of fittings for different weights of pipe, such as the standard cast or malleable iron, extra heavy, and hydraulic. The fittings may be plain or have banded or beaded ends. The plain type is generally used for low pressure gas and water lines, house plumbing, and railing work. The use of screwed fittings in general is not recommended for sizes above six inches. When the size exceeds six inches it is preferable to employ fittings having flanges.

PIPE FLANGE FACES. Pipe flanges which have the entire face of the flange faced straight across, and use either a full face or ring gasket, are commonly employed for pressures less than 125 pounds on steam and water lines. The best results are obtained by using a fairly thick gasket, so that the gasket will have sufficient pressure exerted on it by the bolts to make a tight joint before the outside edges of the flanges meet. The full-faced gasket is preferred by some, because it may be installed more readily and is more likely to be concentric with the bore of the flange than that of a ring gasket, but it has no other advantages. A ring gasket, properly proportioned and correctly applied, will make just as tight a joint as a full-faced gasket, at considerable less expense and with less pulling up on the bolts.

Raised Face, Smoothly Finished for Gaskets. — This type of face is made by raising the face of the flange between the bore and inside of the bolt holes from $\frac{1}{32}$ to $\frac{1}{16}$ inch above that of the remainder of the flange. This type of joint is most satisfactory on high-pressure steam lines, and is the most generally used. With this style of face, ring gaskets are employed, and a greater pressure per square inch of gasket is obtained by pulling up on the bolts than would be obtained with similar bolts on a full-faced gasket. The raised face prevents the touching of the outside edges of the flanges, and the entire pressure exerted by the bolts is transmitted to the gasket, which gives a maximum efficiency and resistance against leakage.

Raised Face, Ground Joints. — This style of face is identical with that employed when gaskets are used, excepting that the raised face is ground to an absolute metallic joint. This eliminates the use of gaskets. This style of joint was popular before a satisfactory gasket material was found, and was employed considerably on superheated steam lines. There are now on the market gaskets which are employed for temperatures as high as 800 degrees F.; the successful use of these gaskets has to a considerable degree reduced the number of ground joints used in steam lines. See also Corrugated Flanges, and Tongue-and-groove Flanges.

PIPE FOR ACIDS. Pipes for carrying acid liquids, when made from steel, will usually last for a short time only. Wrought-iron pipes will last somewhat longer, but are not satisfactory. A steel to which 0.5 per cent of copper has been added has given good results for pipes of this kind. Valves made from ferro-silicon will resist the corrosive action of acid liquids to a considerable extent. Their first cost is higher, but their resistance to the action of the acid warrants their use.

PIPE JOINT CEMENTS. See Cements for Joints.

PIPE, LEAD. See Lead Pipe.

PIPE OF RIVETED TYPE. Very large sizes of pipe are frequently made from boiler sheet steel and provided with riveted joints, the seams being longitudinal or helical. This class of piping is frequently used in large hydraulic installations where the ordinary pipe sizes would be of insufficient capacity for the volume of water passing through them. The helical-seam riveted pipe was invented by John B. Root, and by him termed "spiral riveted pipe." The helical seam makes it possible to obtain in a riveted pipe practically the full strength of the plate; with a longitudinal riveted seam, from 60 to 65 per cent of the strength of the plate is all that can be expected of the riveted seam.

PIPE REAMERS. Pipe reamers are used for reaming taper holes previous to tapping by standard taper pipe taps. They are made in sizes cor-

responding to those of pipe taps, and the taper is the same — $\frac{3}{4}$ inch per foot. They are fluted with the same kind of cutters as are used for straight reamers of sizes corresponding to the diameter at the small end of the pipe reamers.

PIPES, STEAM-FLOW CAPACITY. See Darcy's Formula.

PIPE STRENGTH. The strength of high-class piping material is about as follows: Cast iron, tensile strength, from 15,000 to 18,000 pounds per square inch; copper (cold), 30,000 pounds per square inch; wrought iron, 48,000 pounds per square inch; steel, 60,000 pounds per square inch; brass, 50,000 pounds per square inch; lead, from 1600 to 2400 pounds per square inch. Electrodeposited copper pipes are said to be 50 per cent stronger than ordinary copper pipes. The strength of brass, copper, and other nonferrous piping should be as follows: Brass piping, 7000 pounds per square inch; copper piping, 6000 pounds per square inch; Benedict nickel piping, 14,000 pounds per square inch; and Monel metal piping, 20,000 pounds per square inch. Brass and copper pipe should not be tested, however, beyond 1000 pounds per square inch, and Benedict and Monel metal pipes should not be tested beyond 2000 pounds per square inch.

PIPE TAPS. The pipe tap is used for tapping standard pipe sizes. It is a taper tap the taper of which is $\frac{3}{4}$ inch per foot. There are three important points to take into consideration in making taper taps. In the first place, the threading tool must be presented to the tap at right angles to the axis of the tap, and not at right angles to its tapered surface; except in the case of taper taps with Whitworth thread form, when the threading tool is presented to the work at right angles to the tapered surface. In the second place, taper taps should, if possible, be turned on lathes provided with taper attachments, and not by setting over the tailstock of the lathe; and, finally, proper relief should in all cases be given a taper tap.

PIPE, TEST FOR WROUGHT-IRON AND STEEL. Wrought-iron pipe may be distinguished from steel pipe by testing the material in the pipe for manganese, which is present in the steel pipe, but is not present, except possibly as a trace, in wrought iron. A method of making the manganese test is as follows: Place a clean, bright chip or filing of the metal to be tested, about the size of a pin-head, in a porcelain crucible; add six drops of pure nitric acid, and heat; add two drops of silver nitrate solution, then one crystal of ammonium persulphate not greater than $\frac{1}{8}$ inch in diameter; warm the solution, but do not let it boil. If the metal is steel, a pink color will begin to develop, and at this point the crucible should be removed from the source of heat, when a very decided red coloration will result. If no color develops, but a small amount of dark residue remains in the dish the metal is wrought iron.

PIPE THREAD. The American standard taper pipe thread, also known as the American Briggs standard and as the Briggs standard, is a 60-degree vee thread, truncated equally top and bottom by an amount equal to 0.033 times the pitch of the thread. The taper of the thread, on the diameter, is $\frac{1}{16}$ inch per inch or $\frac{3}{4}$ inch per foot. As far as the thread on the product is concerned, no change has been made from the former American Briggs standard; but to allow for a reasonable amount of wear on the taps and dies, thus making for more economical production, a modification has been made on the gages. This consists of reducing the crest of the thread gage by truncating it an amount equal to 0.10 times the pitch from the theoretical sharp point. If an old gage is correct in all other respects, it can easily be made to conform to the present standards by grinding off the excess metal at the crests of the threads. The dimensions of standard pipe threads are given in tabular form in engineering handbooks.

Pipe Threads without Taper. — Straight-threaded female wrought-iron or wrought-steel couplings of the weight known as " standard " may be used with *taper-threaded* pipe for ordinary pressures, as they are sufficiently ductile to adjust themselves to the taper male thread when properly screwed together. For high pressures, only taper male and female threads should be used. The use of this straight thread for male parts is only recognized for one or two very special applications, which are seldom, if ever, required in ordinary practice.

The following information conforms to the American standard pipe threads and to the standard approved by the National Screw Thread Commission: The straight pipe thread has the American or Briggs tapered pipe thread in regard to pitch and depth of thread. The basic pitch diameter for straight pipe threads equals the pitch diameter at the gaging notch of the tapered plug gage. Occasionally it is advisable to use a straight pipe thread of the largest diameter it is possible to cut on a pipe. This thread has also been standardized and is designated as the " maximum external and minimum internal lock-nut threads." The pitch of this lock-nut thread is the same as the pitch of a standard taper thread of corresponding size. To illustrate the difference between a straight lock-nut thread and the straight pipe thread first referred to, consider the difference between the diameters of the 1-inch normal size. In the case of the straight pipe thread the basic pitch diameter is 1.2386 inches, whereas, in the case of a lock-nut thread, the maximum pitch diameter for an external thread is 1.2603 inches. The straight external pipe threads are recommended only for special applications, such as long screws and tank nipples. In gaging, the tapered working plug gage for the American or National standard is used, allowing the same tolerance for the notch as for a taper thread.

PIPE THREAD, BRITISH STANDARD. The form of thread is that of the Whitworth system; the sides of the thread form an angle of 55 degrees with each other, and the top and bottom of the threads are rounded to a radius equal to $0.1373 \times$ the pitch of the thread. For taper pipe threads the taper is $\frac{3}{4}$ inch per foot, or $\frac{1}{16}$ inch per inch, measured on the diameter. This system has been approved by the British Engineering Standards Association as the standard pipe thread system in Great Britain, and is known as the " British Standard Pipe Thread for Iron and Steel Pipes and Tubes."

PIPE THREAD FOR FIXTURES. The special straight-fixture pipe thread consists of a straight thread of the same pitches as the American standard pipe thread, but having the U. S. form. This thread, as its name implies, is used for fixture work to hold parts together, but not to make tight threaded joints. The male thread is assembled with a standard taper female thread, while the female thread is assembled with a standard taper male thread. This thread is used on lighting fixtures and work of a similar class when it is desired to have the joint " make up," or stop, on the thread. The gages used are straight-threaded limit gages.

PIPE THREAD FOR LOCK-NUTS. The lock-nut pipe thread is a straight thread of the largest diameter which can be cut on a pipe. The thread form is identical with that of the American or Briggs standard taper pipe thread. This lock-nut thread is used only to hold parts together, or to retain a collar on the pipe. It is never used where a tight threaded joint is required.

PIPE THREADING MACHINES. There are two general types of pipe threading and cutting-off machines. The most common type is so arranged that the pipe is revolved while the thread is cut by stationary dies; with the other type, the pipe is held stationary while the die-head is revolved. The die-head contains several equally-spaced chasers, the number depending upon the pipe sizes for which the machine is intended. The die-head is so arranged that these chasers can be moved after a thread has been cut, thus permitting them to be withdrawn from the threaded end. A common method of securing this outward movement is by means of a cam ring which is turned slightly by a hand lever. The die-head is so constructed that the chasers are locked when in the cutting position, and provision is made for adjusting them in order to cut threads which are either larger or smaller than the standard size. The chasers should preferably be so located or ground that the front of each chaser will have a certain amount of rake, in order to insure cutting a clean thread, and also to reduce the amount of power required for the threading operation. The *cutting-off attachment* is a feature common to pipe threading machines in general.

This attachment is located directly back of the die-head, and is used for cutting off pipes preparatory to threading. Some pipe threading machines have a *reaming attachment* for removing the burr which is formed on the inside of the pipe by the cutting-off tool.

PIPE WORKING PRESSURES. Standard weight pipe is commonly used for heating work, exhaust lines, and all pressures below 100 pounds per square inch; extra heavy pipe should be employed for pressures from 100 to 200 pounds per square inch, and where there is liable to be considerable corrosion. These pressures are far below the ultimate strength of the pipe. Special hydraulic pipe for service on lines requiring the highest possible grade of material and workmanship are bored from solid forgings and are made to order for pressures up to 10,000 pounds per square inch. If seamless steel tubes are assumed to have a strength of 100 per cent, butt-welded steel pipe has a comparative strength of 73 per cent, and lap-welded steel pipe of 92 per cent. From this it will be seen that the strength of a butt-weld is only about 80 per cent of that of a lap-weld. The relative strengths of wrought iron and steel pipe are as follows: Butt-welded wrought-iron pipe has 70 per cent of the strength of similar butt-welded steel pipe, and lap-welded wrought-iron pipe has 57 per cent of the strength of similar lap-welded steel pipe.

PISTON ALLOYS, ALUMINUM. See Aluminum Piston Alloys.

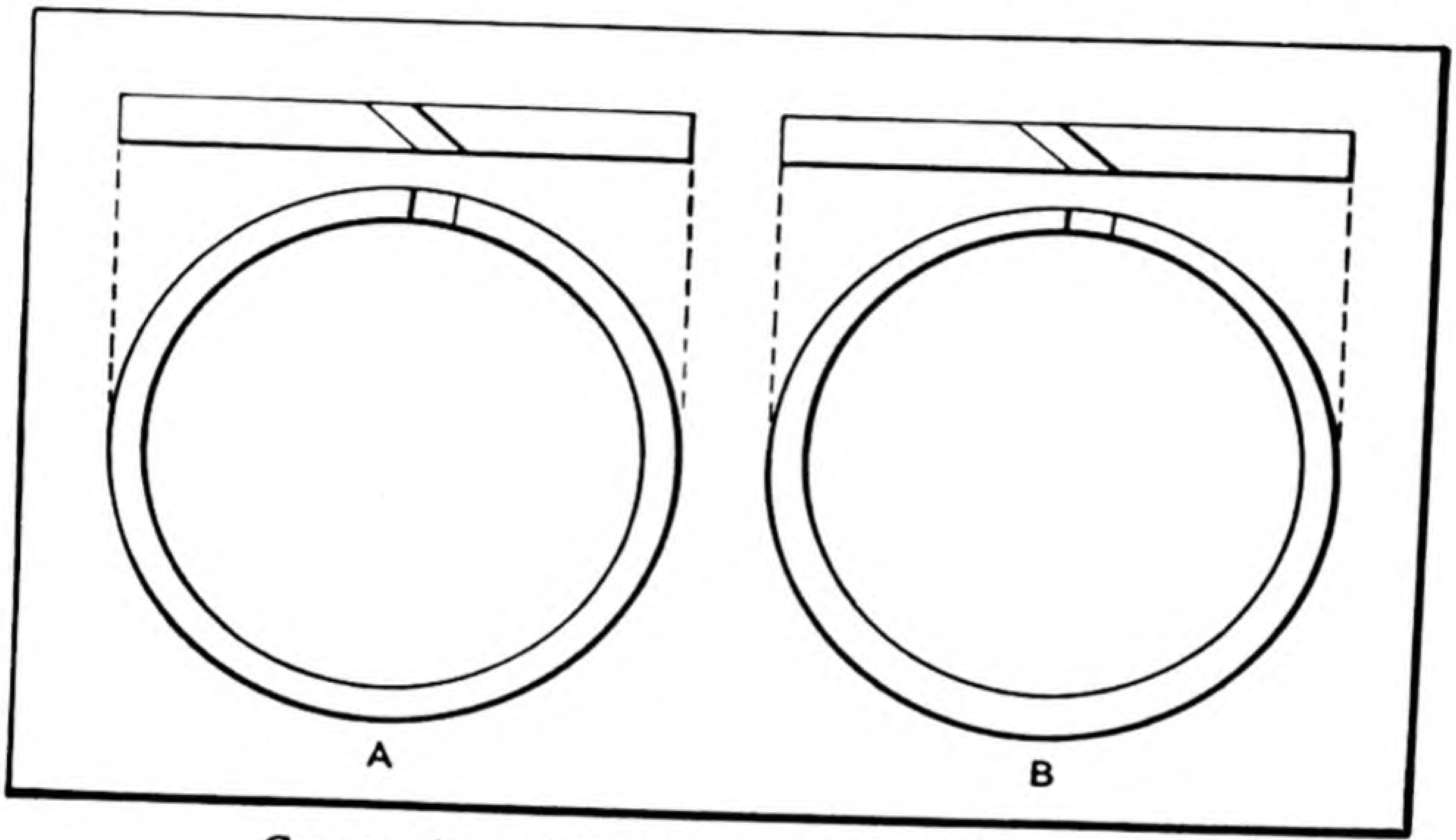
PISTON ALLOWANCES FOR GAS ENGINES. A gas engine piston should fit into the cylinder so as to allow for the necessary oil film and to provide for slight distortions in shape under heat, but still close enough to prevent "piston slap." The question of the ideal allowance to make is considered apart from that of manufacturing tolerances. Some engineers use the very convenient rule of making the piston 0.001 inch small for each inch diameter of the cylinder bore, but the following rule comes closer to actual requirements: Allow from 0.002 to 0.0025 inch as a maximum for each inch of cylinder diameter above two inches. The fit of the piston ring in the groove is another important matter. The ring must be loose enough to operate freely, but close enough to prevent leakage. The minimum safe allowance is 0.0005 inch and the tolerance on both the ring and groove must be given in such a way that this allowance is not diminished. See Piston-ring Widths.

PISTON AND PISTON-RING OVER-SIZES. The S.A.E. standard over-sizes for pistons and piston-rings are 0.005, 0.010, 0.015, 0.020, 0.030, and 0.040 inch. Larger over-sizes when necessary should be in multiples of 0.010 inch.

PISTON DISPLACEMENT. Piston displacement is the volume which is swept through by a piston working in a cylinder. This volume is equal

to the area of the piston multiplied by the length of its travel. See also Pump Displacement.

PISTON PACKING RINGS. In order to secure a tight joint between a piston and the cylinder in which it operates, piston or packing rings are used, the function of the rings being to seal the clearance space between the piston and cylinder and form as nearly as possible a tight joint. These rings vary greatly in design, many attempts having been made to construct a ring that would give a perfectly tight joint. Two of the simplest types of piston rings are shown in the illustration. These cast-iron rings are inserted



Concentric and Eccentric Piston Packing Rings

in grooves in the piston, and are compressed sufficiently, when assembled in the cylinder, to bear tightly against the cylinder wall. The concentric ring *A* is of uniform thickness, whereas the eccentric ring *B* varies in thickness, as the illustration shows, the bore of the ring being somewhat off center. The reason for making a ring eccentric is to obtain a uniform pressure against the cylinder wall all around the circumference. The thickness of concentric rings should equal the cylinder diameter $\div$ 27.5, if made of good cast iron. The outside diameter of a finished eccentric ring before being split should equal 1.027 $\times$ cylinder diameter, the maximum thickness of the ring being equal to $\frac{\text{cylinder diameter}}{27.5}$ and the minimum thickness equal to one-half the maximum. Practically all engine piston rings are made of cast iron and a close-grained tough gray iron is recommended.

PISTON-RING PEENING. See Peening Piston-rings.

PISTON-RING WIDTHS. According to the S.A.E. recommended practice, the nominal piston-ring width is basic and the tolerance is minus

0.0005 inch and plus zero. Limits for the widths of piston-ring grooves are not specified because the fits and tolerances depend upon the particular conditions existing for each application.

PISTON VALVE. The piston type of slide valve for steam engines is identical in its action with the plain slide valve except that it is circular in section instead of being flat or rectangular. The advantages claimed for this type of valve are that it is balanced against the steam pressure; the working edges of the valve are opposite the ends of the cylinder so that the steam ports are short and the clearance comparatively small; when used on high-pressure cylinders, steam may be admitted around the valve center and exhausted on the outside, thus protecting the valve-stem packing from the high-pressure and high-temperature steam. The valve slides in special bushings which may be renewed when worn. Many modern locomotives are fitted with cylindrical or piston valves, instead of flat-seated slide valves. These piston valves have packing rings at the ends which form the working edges and control the points of admission and release of the steam to and from the cylinders. The chambers or steam chests for the piston valves are provided with linings or bushings in which the steam ports are located.

PITCH AND LEAD OF SCREW THREAD. The terms "pitch" and "lead" of screw threads are often confused. The pitch of a screw thread is the distance from the center of one thread to the center of the next thread, whether the screw has a single, double, triple, or quadruple thread. The *lead* of a screw thread is equal to the distance a nut will move forward on the screw, if it is turned around one full revolution. The pitch and lead of a single-threaded screw are equal. With a double-threaded screw the nut will move forward in one revolution, an amount equal to twice the pitch, so that the lead of a double-threaded screw equals twice the pitch. The lead of a triple-threaded screw equals three times the pitch, and the lead of any other multiple screw can be determined by multiplying the number of threads by the pitch. The lead may also be expressed as the distance from center to center of the *same* thread, after one turn.

PITCH CIRCLE. The pitch circles of two spur gears in mesh always intersect the common center line at the point where the line of action crosses this center line. Ordinarily a pair of involute gears is designed for a given center-to-center distance, but these gears might be separated somewhat and it would still be possible for one to transmit motion to the other at a uniform rate, although this would cause a certain amount of backlash or play between the intermeshing teeth. However, if two gears were assembled so that the center distance was somewhat greater than standard (as is sometimes done to meet a special condition) the pitch circles would

be enlarged and the pressure angle increased, but the base circles would remain the same, the involute curvature of the teeth not being changed. The reason why the pitch circles would become larger will be apparent when it is remembered that the radius of each pitch circle is equal to the distance from the gear center to the *pitch point* or the point where the line of action intersects the common center line. See also Pitch Diameter.

PITCH CONE. The pitch cone of a bevel gear is equivalent to a cone which, if mounted on the shaft in place of the bevel gear, would drive or be driven by the frictional contact with the pitch cone of its mating gear in the same velocity ratio (if no slip occurred) as that of bevel gears having correctly formed teeth.

PITCH CONE ANGLE. The pitch cone angle of a bevel gear is the angle which the pitch line makes with the axis of the gear. This is sometimes referred to merely as " pitch angle."

PITCH CONE RADIUS. The pitch cone radius of a bevel gear is the distance measured on the pitch line from the vertex of the pitch cone to the outer edge of the teeth. This dimension is also known as the " cone distance."

PITCH DIAMETER. The pitch diameter, as ordinarily applied in the design of spur and bevel gears, equals the number of teeth divided by the diametral pitch. The actual pitch circle, however, when, say, two spur gears are in mesh, is established by the intersection of the line of action and the common center line. The pitch diameter of a bevel gear is the distance across the gear at the point where the pitch lines intersect the outer edges of the teeth; in other words the pitch diameter is measured at the large ends of the teeth. See Pitch Circle.

PITCH DIAMETER OF SCREW. On a straight screw thread, the " pitch diameter " is equivalent to the diameter of an imaginary cylinder which would pass through the threads at such points as to make the width of the threads and the width of the spaces cut by the surface of the cylinder equal. Thus the pitch diameter is equal to the outside diameter minus one thread depth.

PITCH OF GEAR. Pitch, as used with reference to gear teeth, defines the sizes of the teeth. Two kinds of pitches are used, *circular pitch* and *diametral pitch*. The circular pitch is the distance along the pitch circle from the center of one tooth to the center of the next. The pitch circle at the larger or outer ends of the teeth is used for determining the circular pitch of a bevel gear. The diametral pitch is the ratio or quotient obtained by dividing the number of teeth by the pitch diameter.

PITCH OF RIVETS. The pitch of rivets is the distance from the center to center of adjacent rivets. The pitch should be as large as possible without impairing the tightness of the joint when under pressure. For single-riveted lap-joints in the circular seams of boilers which have double-riveted longitudinal lap-joints: Pitch = $d \times 2.25 = t \times 5$, approximately, in which d = the actual diameter of rivet (in parallel hole); t = thickness of plate. For double-riveted lap-joints: Pitch = $8\,t$.

The following rules for rivet spacing apply to bridge and structural work. The minimum center-to-center distance or pitch should not be less than three times the rivet diameter. In bridge work, the pitch should not exceed six inches, or sixteen times the thickness of the thinnest outside plate, except in special cases. The distance between the edge of any piece and the center of the rivet hole should not be less than $1\frac{1}{4}$ inch for $\frac{3}{4}$- and $\frac{7}{8}$-inch rivets, except in bars less than $2\frac{1}{2}$ inches wide; when practicable, this distance should be at least two rivet diameters for all sizes and should not exceed eight times the plate thickness. For flanges of girders and chords carrying floors, the pitch should not exceed four inches. For plates in compression, the pitch in the direction of the line of stress should not exceed sixteen times the thickness of the plate, and the pitch in a direction at right angles to the line of stress should not exceed thirty-two times the thickness, except for cover plates or top chords and end posts, in which the pitch should not exceed forty times the thickness.

PITCH POINT. The term "pitch point" as applied to spur gearing, indicates that point where the line of action intersects the common center line of two gears in mesh.

PITOT TUBE. The Pitot tube is used for measuring the velocity of fluids in motion. It consists simply of an open tube having a right-angle bend. The tube is placed in the stream of water (the pressure of which is to be measured) in such a position that one of the open ends is directed against the flow of the water while the other end projects above the surface of the water. The height to which the water rises in the end projecting above the surface is equal to the velocity head. Modifications of the Pitot tube are also used for measuring the flow of water and gases in pipes.

PIT-SAW FILE. This type of file is a full half circle in section and is sometimes referred to as a frame-saw. The form is blunt and the teeth single-cut, second-cut. These files are used for filing the teeth of what are known as pit-saws and frame-saws.

PITTING. In boilers, pitting is the formation of conical or spherical depressions in the plates. Pitting is caused by the action of oxygen or chlorine released from the feed water when heated. When the depressions

are small and close together, this condition is known as honeycombing. Magnesium and calcium chloride contained in the boiler feed water are frequently the causes of pitting.

PIVOT SWITCHES. It sometimes happens that it is necessary to connect a source of power to any one of three or more circuits, and this can be most conveniently done with a pivot switch. A pivot switch is a lever switch having its hinge arranged so it can be revolved around its center, a number of contacts being located on the circumference of a circle with the hinge as its center. With this arrangement, the blade can be closed into any one of these contacts. Pivot switches are usually single-pole, but may be made double- or triple-pole in the smaller capacities. In the latter case, the switches have to be double-break, as the pivot or hinge cannot be a current-carrying part.

PLANAMILLING AND PLANATHREADING. The form milling (internal or external) of one of more circular surfaces by a planetary movement of one or more milling cutters mounted on an arbor, is known as *Planamilling.* The work is held by a stationary chuck; the rotating cutters are fed automatically over or through the work to a set stop, and then fed radially into the work to the proper depth of cut; now the cutter arbor travels slowly in a circle and the cutters mill to an accurately finished diameter. When the cutter arbor has made one complete revolution the cutters are automatically lifted from contact with the work and withdrawn while the work is being changed. While this process shows large saving in machine time on a single diameter, greater savings are effected in the simultaneous milling of two or more concentric bores, especially when the innermost bore is larger than the through bore, the machining of which would require more than one set up on some other type of machine. In *Planathreading* a thread milling cutter of the required pitch is mounted on the arbor and revolved in a circle as in planamilling. The length of the cutter is the same as the axial length of the thread to be cut, plus two threads. While the arbor with the cutter or cutters revolves one revolution, it is also fed axially one thread. One planetary revolution of the arbor completes the operation. Depending on the location of the shoulders of the work, planathreading and planamilling may be performed simultaneously.

PLANER. Planing machines are used principally for producing flat or plane surfaces in connection with the finishing of machine parts. The natural function of a planer is to produce plane or flat surfaces, although it is sometimes used for forming irregular or curved surfaces. There are three general classes of planing machines which are commonly known as planers, shapers, and slotters. *Shapers* are smaller machines than planers and are used for lighter work, whereas *slotters*, which might be considered

as vertical planing machines, are used for operations that could not be done readily, if at all, on regular planers or shapers. These three classes of planing machines differ radically in their construction. There are several different types of planers which have been designed for planing certain general classes of work to the best advantage. There is, however, what might be called a *standard* design which is found in all machine shops and which is adapted to general planing operations. While the construction or design of planers of different makes varies somewhat, there are certain features which are common to all machines of the standard type.

Open-side Planers. — The open-side type of planer has a massive column on one side of the table only so that the opposite side is open and unobstructed, which greatly increases the range of the machine. The cross-rail or beam upon which the tool-heads are mounted is of very rigid design and has a broad bearing surface on the column to prevent deflection due to the thrust of the cut. The chief advantage of an open-side planer is that it can be used for machining large castings which would not pass between the housings of a two-housing planer of ordinary size. The driving and feeding mechanism of an open-side planer is similar, in principle, to that used on the regular type.

Open-side Plate Planer. — The open-side plate planer is a type of planing machine designed especially for planing the edges of steel and iron plates. While this machine is known as a *planer*, it is, in reality, a modification of the shaper, since the planing tool is given a reciprocating movement, and the work-table and work remain stationary.

Combination Planer. — In shops where the use of an open-side planer would be exceptional, but necessary, at times, what is known as a combination planer has been used to a limited extent. One planer of this class is equipped with two housings which are similar to the housings of an ordinary planer. When the work is too wide to pass between these housings, one is moved back along the bed and a box-shaped casting or brace is interposed between the housing and the cross-rail to support the latter against the thrust of the cut. By adjusting the housing backward in this way, a standard form of planer is converted partially to an open-side type.

Crank Planer. — The crank planer, as the name indicates, derives its motion from a crank instead of from a rack and gearing. This crank motion is generally the Whitworth quick-return movement, or some modification of it. Planers of this type are made in small sizes, a 20- by 20- by 24-inch machine representing a typical size. These machines are especially adapted to rapid operation on comparatively short work; in fact, the general class of work is similar to that done on a shaper. The crank planer, as compared with the standard planer, has the advantage that the stroke is definite and exact, owing to the fact that the motion is derived from a

crank mechanism; therefore, it is possible to plane right up to a line without the danger of over-running. While the general characteristics of a crank planer are similar to those of the shaper, it differs from the latter in that the work-table moves to and fro, the same as with the regular planer, whereas, in the case of the shaper, the tool itself is traversed back and forth across the work. Owing to the speed and accuracy of a crank planer, it is particularly adapted for tool and gage work.

Traveling-head Planer. — Traveling-head planer is the name given a certain type of planing machine that operates on the same principle as a draw-cut shaper, although of very different construction. The planer has a large floor plate for holding the work, and a vertical column upon the face of which is a slide. The latter carries the ram for planing and also the ram operating mechanism. The slide and ram have a vertical adjustment upon the column, the arrangement being similar, in this respect, to a horizontal boring machine of the floor type. As previously intimated, the cutting is done on the return stroke of the ram, so that the thrust of the cut is taken directly by the column. The reciprocating motion of the ram is controlled by two special friction clutches. This planing machine may also be used for milling and boring operations, thus enabling planed parts to be finished complete at one setting, in many instances.

Duplex Planer. — The duplex planer differs from the ordinary type in that there are housings (equipped with a cross-rail and tool-heads) at each end of the planer bed. The housings at one end may be adjusted on the bed for varying the distance between the two sets of planing tools. This type of planer is intended more especially for such work as planing the ends of locomotive connecting-rods. When doing work of this kind, the rod is clamped to the table in such a position that a cut is taken over one rod end when the table is moving in one direction, and the opposite end is planed when the table movement reverses; therefore, when using this machine, there is no idle return period, and the planer table moves at the same speed in both directions, the tools being constantly in operation.

Pit Planer. — Planers of this class are intended for very large unwieldy work, such as armor plate planing, etc. They are so arranged that the work remains stationary and the tool-heads, together with the cross-rail and its supporting columns, are given a traversing movement. The vertical columns between which the cross-rail is held are mounted upon parallel beds, one of which extends along each side of the work-table. One make of pit planer intended for armor plate work is equipped with a cross-rail which swivels 90 degrees each way from the vertical, and carries two tool-heads. For cross-planing, one of the two heads can be traversed along the cross-rail.

Breast Planer. — Breast planers are a special type used for planing the

edges of armor plate or other work that could not readily be done, if at all, on a regular planing machine. They are usually built for cross-planing, the planing operation being done by a tool-head which is traversed along a cross-rail. Power may be applied, however, for longitudinal motion, in which case the work can be planed lengthwise, as well as crosswise.

Frog and Switch Planer. — Frog and switch planers are so named because they are intended primarily for shops manufacturing switch parts and rail crossings or frogs for railways. They are also adapted for other work, especially of a heavy nature, such as planing large steel forgings, steel castings, etc. Great driving power and extreme rigidity under maximum duty are characteristic features of these planers. Planers of this class usually have an adjustable cross-rail, the same as a standard planer, although some are so designed that the cross-rail can only be located in one of three fixed positions. See also Rotary Planers.

PLANER ATTACHMENTS. While planers ordinarily do not have much auxiliary equipment, there are certain planer attachments which increase the range or capacity of the planer, and others which make it possible to plane special classes of work. Among the planer attachments commonly used may be mentioned the extension tool-head which increases the planer capacity for handling exceptionally wide work, the floor stand or independent housing which still further increases the planer capacity, index centers for planing parts that require dividing or spacing, and various other attachments such as those for planing curved surfaces, spiral grooves, etc. These special attachments are needed more particularly in shops handling a wide variety of work, and especially those having a rather limited planer equipment.

PLANER BELTS. The belt which drives the planer on the forward or cutting stroke is usually the crossed belt and should be so crossed that the side running back to the countershaft is on the inside next to the planer housing. Then the side of the belt which is acted upon by the shifter for reversing the motion of the planer table, forces the other side with it and the reversal occurs more rapidly than would otherwise be possible. Planers should always be driven by double belting.

PLANER NET CUTTING SPEED. The net cutting speed of a planer is equal to the number of feet traversed by the tool in a given time while cutting or planing, and it is less than the speed of the table on the forward or cutting stroke, because of the idle or return period, when no work is being done. The net cutting speed equals the forward cutting speed divided by the total time required for the forward and return movements. If the cutting speed were 40 feet per minute and the return speed 120 feet per minute, a forward movement if continued for a distance of 40 feet would require one minute and the return stroke one-third minute, or $1\frac{1}{3}$ minute

for forward and return strokes. Therefore the number of feet per minute traversed by the tool while actually cutting, equals $40 \div 1\frac{1}{3} = 30$ feet per minute.

PLANER ORIGIN. The names of six or seven English inventors are associated with the planer which was used at such an early period in the United States that there may also have been independent developments. The French were, to a certain extent, pioneers as a form of planing machine was invented by Forq in 1751, although the design is not along the lines of the early English types. A planer is said to have been built by Matthew Murray in 1814 in order to machine the D-slide valve for steam engines.

The oldest existing planer is in the South Kensington Museum in London. This planer, in its general principle of operation, resembles the modern type in so far as the relationship of a tool-head and table are concerned. The table is reciprocated by the pilot type of handwheel acting through a sprocket and chain transmission. This chain is of the ordinary forged link type. The tool-slide has vertical and horizontal feeding movements, angular adjustment, and a hinged tool-block for lifting during the return stroke. This planer was built by Richard Roberts in 1817, and evidently it was made without the use of a planer as chisel and file marks on the bed and ways indicate hand work.

In 1820, George Rennie built a screw-driven planer which had a revolving cutting tool — an idea evidently considered quite important by several early designers. In this same year, 1820, Joseph Clement built a planer provided with two cutting tools, one being for the forward and the other for the return stroke. This was known as the "Great" planer and the bed operated on rollers to reduce frictional resistance. It is believed that the first planer in America was built in 1836 in the shop of Silver & Gay Co., North Chelmsford, Mass., although a planer is said to have been built at about the same time by Pedrick & Ayer of Philadelphia.

PLANER SIZE. The size of a planer is equivalent to the width and height of the largest part that will pass between the housings and under the cross-rail, when the latter is raised to its highest position. For instance, a 38- by 38-inch planer is one that will plane work approximately 38 inches wide and 38 inches high. Sometimes the maximum length that can be planed is included when designating the planer size. Thus a 36-inch by 36-inch by 8-foot planer means that a piece 36 inches square will pass between the housings, and that a length of 8 feet can be planed.

PLANERS, GEAR. See Gear Planers of Templet Type.

PLANER TOOLS, RIGHT- AND LEFT-HAND. Planer tools are usually designated as right-hand when the cutting edge is on the right-hand side,

assuming that the tool is in a horizontal position and is seen from above, whereas left-hand planer tools have the cutting edge on the left-hand side. If a planer tool is in the working position, then, as viewed from the front of the planer, a right-hand tool has its cutting edge on the left-hand side and it feeds from right to left. The foregoing method of designating right- and left-hand planer tools has never been applied universally, but it seems to agree with the most prevalent usage at the present time. It would be preferable, however, in case these names were standardized, to have them agree as to the " hand " for both lathe and planer tools of the same general type or shape. See also Lathe Tools, Right- and Left-hand.

PLANETARY GEARING. Planetary gearing (also called differential and epicyclic gearing) is the common name for a special type of mechanism used in the transmission of mechanical motion. It is composed of a series of mounted toothed wheels in gear, the distinctive characteristic being that some of the wheels turn on movable centers, while the others turn on fixed centers. Its specific advantage is that it may give very little or very great change in angular velocity with the same or the opposite directional relation, all within very small compass. Usually the change in angular velocity is in the nature of a reduction, and very large reductions are readily obtained. The wheels that turn on movable centers are termed " planet wheels " and those that turn on fixed centers are called " sun wheels."

PLANIMETER. The planimeter is an instrument used for determining the area of a figure on a drawing or map by moving a " tracing point " of the instrument along the outline of the area or surface to be measured. The irregular shape of the area does not influence the accuracy of the reading. A common form of planimeter is the " Amsler *polar planimeter*." The results obtained by the planimeter are correct within an error of about one per cent. A more elaborate instrument than the polar planimeter is known as the *rolling planimeter*. This instrument is more expensive than the polar type but results that are correct within 0.1 per cent can be obtained by it. The whole instrument rolls forward and backward in a straight line while the tracing point follows the outline of the surface to be measured. The planimeter is used for measuring areas in general, and especially for measuring the areas of indicator cards. Some forms give the mean effective pressure directly, without computations, by changing the scale to correspond with the spring used in the indicator.

PLANISHING. A planishing operation is one involving the use of a hardened tool having a very smooth working surface which imparts a fine finish to a steel or other surface by either a rubbing or a rolling process, depending upon the nature of the work. The tool used may either be in the form of a hand-tool having a smooth end which is held into contact

with the rotating surface, or it may consist of a hardened and polished roller or of a pair of rolls. In rolling finished shapes in steel mills, the pass next to the last one is called the " planisher," or sometimes the " leader." Planishing rolls are also used for certain finishing operations on sheet metals. For example, the second pair of rolls used for finishing coin metal by cold-rolling prior to minting, are known as planishing rolls. Cylindrical parts which have been turned in the lathe are sometimes finished by rotating in contact with a hardened and polished roller, the object being to obtain a dense surface and a smooth finish. This planishing operation, however, is not common, and is confined largely to certain railroad shops where it is applied to the fitted ends of crankpins and axles. In metal spinning, a " planisher " is used for planishing or burnishing the surfaces of spun parts. This tool is manipulated by hand, and has a hardened and polished end which removes unevenness as it rubs over the rapidly rotating part, the surface of which is made smooth and dense. The term " planishing " is also applied to a hammering operation, which consists in giving parts a dense, smooth finish by a rapid succession of blows delivered by the highly polished dies or hammers of a planishing hammer. Planishing is similar to burnishing so far as the general principle of the process is concerned, and the two terms are used interchangeably for certain operations.

PLANO-MILLING MACHINES. Horizontal milling machines of the planer type are sometimes referred to as *plano-milling machines*, because the general design resembles that of an ordinary planer. When the name " plano-milling machine " is used, it is often applied regardless of the arrangement of the cutter spindles; that is, whether the machine is equipped simply with one horizontal spindle, with vertical spindles on the cross-rail, or with both vertical and horizontal spindles.

PLANT FACTOR. The ratio of the average load to the rated capacity of the power plant, *i.e.*, to the aggregate ratings of the generators, is the plant factor.

PLASTER MOLDS. Plaster-of-paris molds are especially useful as a means of producing small castings for experimental work. A casting made in a plaster-of-paris mold is smoother than one made in a sand mold. Plaster-of-paris alone will not withstand the heat of molten metals, and experience has shown that the addition of asbestos is necessary to insure the success of so-called " plaster-of-paris " molds. Pure plaster would crack when heated, and the castings produced would not be uniform. The percentage of asbestos may be varied according to the material to be cast, although equal amounts of plaster-of-paris and asbestos generally produce very satisfactory results.

The mixing of the plaster is very simple, yet there are several points that require careful consideration. A pan or pail of suitable size is partly filled with water (the amount depending on the quantity of plaster required) and powdered plaster sifted into the water. When the sifted plaster thus piled up reaches the surface of the water, an equal amount of asbestos is added. Care should be taken not to stir the water and plaster-of-paris before adding the asbestos. After the addition of the asbestos the ingredients are stirred thoroughly. The asbestos is used in pulverized form. A small amount of plaster should be poured on the pattern, and a soft brush used to brush the surface of the pattern over with the plaster before filling up the frame. This insures covering the entire surface and prevents the formation of air pockets.

Wooden and metal patterns should be covered with a coat of oil before pouring the plaster. This facilitates the removal of the pattern from the mold after the plaster has set. A mold of this kind will set in from twenty to thirty minutes. The entire matching surface of the drag is covered with a solution of soapy water, which prevents the plaster forming the cope from adhering to that of the drag.

PLASTER-OF-PARIS. Plaster-of-paris is a calcined gypsum from which the water has been driven off by heat. Plaster-of-paris, when diluted with water into a thin paste, sets rapidly, and at the instant of setting, it expands or increases in bulk. This material is, therefore, used for making casts of statuary, etc., as it fills the forms perfectly. It is also used as a pattern material. Plaster-of-paris sets in from three to six minutes, but if, for any reason, it is desired to keep the mass plastic for a longer period, this may be done by adding a drop of glue to a five-gallon mixture. This will keep the plaster-of-paris soft for a couple of hours. Citric acid will also delay the setting of plaster-of-paris for several hours. One ounce of citric acid will delay the setting of one hundred pounds of plaster-of-paris for two or three hours. The acid is dissolved in water before being mixed with the plaster. Plaster-of-paris, when mixed with cold water, has an expansion of about $\frac{1}{16}$ inch to the foot when hardening. If this expansion is undesirable, it may be mixed with warm water or lime water, in which case the expansion is negligible. When mixing plaster-of-paris, water should not be poured on the plaster, but the plaster should be sprinkled into the required amount of water until it sets as a powder upon the surface of the water. Then it should be stirred quickly by hand until the mass attains the consistency of heavy cream, when it is ready for use.

PLASTIC BRONZE. Plastic bronze is an alloy containing 69 per cent of copper, 10 per cent of tin, and 21 per cent of lead. This alloy may be used as a bearing metal.

PLASTIC WOOD. A material known as plastic wood is so called because it is sufficiently plastic to be molded readily with the fingers and it may be used for filling cracks, holes or other defects. It hardens quickly and then can be carved, planed, sandpapered, or turned in a lathe the same as ordinary wood. This material is transported and sold in cans. The manufacturers claim it will adhere to metal, tile, cloth and glass, as well as to wooden surfaces, and that nails and screws will not split it. It may be painted, stained or varnished and has the general characteristics of wood, except that it has no grain. Plastic wood may also be used for filling defects in castings, provided improvement in appearance is the only requirement.

PLATE GAGE. The U. S. standard gage for sheet and plate iron and steel, legalized by act of Congress, March 3, 1893, is frequently referred to as the "standard plate gage." It is adopted by the Custom House department for sheet iron and steel, and is also used by about forty-five sheet and tin-plate manufacturers. The American or Brown & Sharpe gage is used for sheets of non-ferrous metals and the Birmingham Wire Gage for strip steel, leaf spring steel, steel bands, hoops and seamless steel tubing. The Birmingham Gage (B. G.) effective 1914, is the British standard for iron and steel sheets and hoops. It differs from the Birmingham Wire Gage.

PLATEN. This is a name frequently applied to the table of a planer and to the work-holding tables of hydraulic presses, testing machines and certain other classes of mechanical equipment.

PLATINE. The white-metal alloy platine is composed of 43 per cent of copper and 57 per cent of zinc.

PLATING, CHROMIUM. See Chromium Plating.

PLATINITE. A nickel steel containing 42 per cent of nickel has the same coefficient of expansion as glass. It is known as *platinite*, because the only other metal that has this coefficient of expansion is platinum. Both platinum and platinite have been employed in the incandescent lamp for the connecting wire fused into the glass to establish an electric connection between the inside and outside of the bulb. Platinite is used for scientific instruments or for standards of length, because of its peculiar quality of being practically non-expansive when heated to high temperatures.

PLATINOID. Platinoid is an alloy containing 60 per cent of copper, 14 per cent of nickel, 24 per cent of zinc, and 2 per cent of tungsten. The name is derived from the fact that it possesses some of the properties of a platinum alloy.

PLATINUM. Platinum is a grayish-white metal which is very malleable and ductile. This is one of the heavier metals, having a specific gravity

varying from 20.85 to 22.6, according to the treatment it has received. It melts at a temperature of 1755 degrees C. (3190 degrees F.). Its linear expansion per unit length, per degree F., equals 0.00000479. Its electrical conductivity (silver = 100) is about 14.4. Its mean specific heat, from 32 to 212 degrees F., is 0.0323. Its latent heat of fusion is 27.18 calories. The atomic weight is 195.2.

PLOW BOLT. This is a general name for a number of types of bolts employed in the making of plows and cultivators. They are generally short bolts with a countersunk head and provided with a square nut.

PLOW STEEL. The term "plow steel" is a commercial trade name applied to a high grade open-hearth steel used in making wire rope. The name originated in England because of the application of a strong grade of steel wire to ropes used in the mechanical operation of plows.

PLOW-STEEL WIRE. Plow-steel wire is a special kind of very high-grade steel wire having an ultimate strength varying from 200,000 to 350,000 pounds per square inch, according to the diameter of the wire. For wire 0.093 inch in diameter, the tensile strength has been found to be as high as 345,000 pounds per square inch, whereas, for wire 0.191 inch in diameter, the strength is about 200,000 pounds per square inch. The elongation is only about 1 per cent. The composition of the wire is about as follows: Carbon, 0.83 per cent; manganese, 0.59 per cent; silicon, 0.14 per cent; sulphur, 0.01 per cent; phosphorus, nil; copper, 0.03 per cent.

PLUG FUSE. The most common type of fuse is the plug fuse which is generally used on incandescent lighting circuits. These fuses are very compact and consist of a cylindrical porcelain body in which the fuse strip is placed.

PLUG SWITCHES. In a plug switch, the stationary contacts are known as "receptacles" and the bridging member as the "plug." Plug switches may be arranged in either of two ways; the receptacles may be placed one back of the other and the circuit completed by inserting the plug so that it will pass through the first receptacle and into the second; or the receptacles may be placed side by side, and two plugs, connected at their outer ends, inserted to complete the circuit. There are many forms of plug switches, each designed to meet certain conditions.

PLUMBAGO. Plumbago, also commonly known as "black lead," is a name frequently applied to a certain quality of graphite. Plumbago is used in the foundry, for the "blackening" of molds, and mixed with tallow and wax as a lubricant for driving ropes. The main supply of plumbago imported into the United States comes from Ceylon.

PLUNGE-CUT GRINDING. This term has been applied to grinding which is done by directly feeding into the work, a wheel, the face of which is sufficiently wide to cover the entire surface being ground. In the case of parts with surfaces longer than the maximum possible wheel face, the grinding is done by in-feeding along the work at successive intervals, the face of the wheel overlapping slightly each previous cut, until the grinding of the entire length has been done, after which the work is rapidly moved past the wheel to complete it. This method is adapted to the simultaneous grinding of duplicate parts that can be placed in a gang on a mandrel or other convenient chucking device, such as piston rings, ball-bearing cups, roller-bearing cups, collars, and bushings. Single pieces which lend themselves to the application of a wide wheel are also ground in quantity by this method, such as, for example, transmission shafts, axle shafts, propeller shafts, armature shafts, spindles, pistons and work of corresponding kind.

PNEUMATIC CHUCK. This is an air operated chuck used on some turret lathes for holding and rotating work to be machined. The pneumatic operation permits closing and opening of the chuck jaws rapidly.

PNEUMATIC HAMMERS. The pneumatic hammer is a combination of a cylinder, a reciprocating plunger or piston, a valve for automatically controlling the movements of the plunger, and a throttle valve for regulating the flow of air to the hammer from the supply pipe. The first practical pneumatic hammer was developed by Boyer of St. Louis, who, in 1883, patented a chipping machine having a handle or grip and a hand-controlled throttle valve. Improved designs followed, and it was soon evident that there was a large field for pneumatic hammers. Pneumatic hammers are now made in quite a variety of designs, some being intended especially for riveting, and others for such operations as chipping, calking, or scaling. The riveting hammers used on structural work, boiler work, etc., are larger and more powerful and have a longer stroke than those designed more especially for chipping, although the latter are also used for light riveting operations.

PNEUMATIC TIRE. The pneumatic tire was patented in England by R. W. Thomson in 1845. It was not intended originally for the bicycle, but such application was made in 1889 by Dunlop, as covered by a United States patent granted in 1890.

POGGENDORF'S CELL. This is a primary cell or battery practically identical with the Bichromate Cell.

POISSON'S RATIO. If a square bar is stressed in a testing machine in the direction of its length, so that the length increases, there is a contraction in each opposite direction, which produces a decrease in the thick-

ness of the bar. The ratio between the contraction at right angles to a stress and the direct extension is called Poisson's ratio. For ordinary kinds of steel this has a value of about 0.3. If the direct stress is a compressive stress, so as to cause decrease of length in the direction of the stress, then there will be an expansion in each direction at right angles equal to 0.3 times the compression.

POLARIZATION. Polarization is a phenomenon, which occurs on the passage of a current between two electrodes immersed in an electrolyte, and its effect is always to oppose the flow of current by creating a counter-electromotive force. The discharge voltage is equal to the cell potential, as it would be without external load, minus internal resistance drop, minus the polarized counter-electromotive force. The charging voltage is equal to the cell potential (without external load), plus internal resistance drop, plus the polarized counter-electromotive force. Storage batteries are rated in ampere-hours, that is, the battery is rated to give, during discharge, a certain number of amperes during a certain number of hours.

POLAR MOMENT OF INERTIA. The polar moment of inertia of a surface is the moment of inertia with respect to an axis through the center of gravity at right angles to the plane of the surface, and equals the sum of two moments of inertia taken with respect to two gravity axes in the plane of the surface at right angles to each other. The *polar section modulus*, equals, for circular sections, the polar moment of inertia divided by the distance from the center of gravity to the most remote fiber. This method may also be applied with fair accuracy to sections that are nearly circular. For other cross-sections, the polar moment of inertia has been obtained in the form of empirical formulas by means of experiments.

POLAR SECTION MODULUS. The polar section modulus is also known as the section modulus of torsion. See Polar Moment of Inertia.

POLE LATHE. The pole lathe, which was a primitive form, consisted of two poppets supported on a wooden bed, and suspended from the ceiling was a wooden spring-pole, to the free end of which was attached a strong cord. This cord was wound once around the piece to be turned, and the loose end was carried down to the floor where it was formed into a loop for the workman's foot. In improved forms of the pole lathe, a rude treadle was provided instead of the loop. When the foot was depressed, the work-piece was turned by the cord against the cutting tool, the spring-pole depressing at the same time. With the upward lift of the foot, the spring-pole raised the cord and turned the work in the opposite direction. The pole lathe had the serious objection that the work did not turn continuously, but was turned alternately in opposite directions. A very high degree of

skill was required to do satisfactory work, as the turning tool had to be lifted the moment the work began to turn backwards, and had again to be brought to the cutting position when the reverse movement began; hence, the application later of a driving wheel connected by a cord to drive the work continuously in one direction. The driving wheel, which was turned by a crank, was mounted on a separate stand or base placed to one side of the lathe, and was usually provided with three grooves. This type of machine required two workmen, one to turn the crank and the other to handle the cutting tool.

POLISHING. In general polishing is an operation performed by using any wheel that has a polishing abrasive glued to its face, regardless of whether the wheel is made from leather, canvas, or some other material. The term polishing embraces everything from the "flexible-grinding" operations performed on rough forgings such as axes and picks, and the removal of flash from table knives and forks, to the production of the brightest luster, such as is given to surgical instruments, high quality scissors, and other kinds of general hardware. The former class of work, which consists of grinding away metal preliminary to the luster producing process, has been called "flexible grinding." This term is also applied to other operations in which a flexible polishing wheel removes metal preparatory to plating, painting or enameling the surface. In contradistinction to flexible grinding is the process by which the surface of metals is refined by a number of operations until it has been reduced to a degree of smoothness that is known as a mirror finish; that is, a finish such that the light is refracted from the surface as in a mirror. But in general, in the trade, polishing is the term used to cover all this work of refining metal surfaces. Polishing, however, does not include buffing which is done with cloth wheels to which the abrasive is applied loosely instead of imbedding it in glue. See Buffing.

Polishing wheel speeds vary somewhat for different kinds of work, but ordinarily the speed at the periphery of the wheel ranges from 6000 to 7500 feet per minute. Loose muslin wheels of the kind used for buffing often run at from 8000 to 10,000 feet per minute.

POLISHING OR BUFFING MACHINES. The type of machine that is generally used for polishing and buffing operations is usually known either as a polishing or buffing lathe, machine, stand, or head. It is very simple in construction and consists simply of a column and a spindle which is mounted in suitable bearings and provided with means for holding the polishing or buffing wheels. This spindle is rotated very rapidly when the machine is in use, and the wheels are held either between the collars shown or on a tapering screw at the end of the spindle.

Some polishing machines are equipped with polishing belts. The belts used on machines of this type may be of cotton, felt, leather, or abrasive cloth. When plain cloth or leather belts are used, they are prepared for polishing by first applying a coat of glue and then a suitable abrasive to the working surface. Machines of the belt or band type are sometimes provided with a flat supporting plate back of the point where the work is applied to the belt, so that the machine is adapted for polishing flat surfaces.

Some machines are designed to automatically maintain contact between the work and the polishing or buffing wheel so that the entire surface is finished without hand manipulation. Circular parts rotate while in contact with the wheel and a reciprocating device may be used to provide a traversing movement. With square, hexagonal, oval, or unsymmetrical parts, the distance from the center of the work to points along the outside varies considerably, and so a special mechanism must be employed to change the distance between the center of the buffing wheel and the center of the work as the work is revolved. Some machines which automatically present the work to the wheel have multiple-spindle work-heads. With such a machine, the operator loads and removes the work while contact of the work and buffing wheel is made automatically by the intermittent indexing of the work-head.

One type of automatic polishing machine intended for fairly flat parts has a feed belt which carries the parts under a series of polishing wheels. Pieces up to several inches in thickness may be handled, and the machine is built in various widths to accommodate pieces up to about 20 inches wide. Contact between the work and the polishing wheels is maintained by a micrometer adjustment. The machine is built in units, each of which carries an independently operated polishing wheel that is driven by an individual motor. Any number of units may be used in one battery to suit the particular polishing process or desired rate of production.

POLYGONS. A polygon is a plane geometrical figure bounded by a number of straight sides. Strictly speaking, triangles and figures having four sides are *polygons*, but the term is more generally applied to figures having more than four sides. If all the sides are of equal length and the angles between the sides are equal, the figure is called a *regular* polygon.

POOD. A Russian measure of weight, equal to 16.38 kilograms or 36.12 pounds avoirdupois.

POPPET VALVE. The term "poppet valve" is applied to a valve having, ordinarily, a conical surface which engages a conical seat of corresponding angle, thus forming a tight joint by metal-to-metal contact. The valve is usually made of steel or brass and the seat of cast iron. According to S.A.E. recommended practice, the nominal valve diameter equals the

port diameter, and poppet valves and valve seats should have an included angle of 90 degrees, the valve seat and corresponding bearing surface on the valve inclining 45 degrees from the axis or center line. Over-all lengths of the valves are measured from the large diameter of the valve seat to the tip of the stem. The valve stem tips should be hardened to give a scleroscope reading of from 55 to 65 after finishing.

POPPET VALVE LIFT. Conical-seated poppet valves require a lift varying from one-fifth to one-fourth greater than corresponding flat-seated valves. Assume that D equals the minimum diameter of the valve seat; d equals diameter of pipe to which valve opening must correspond; and r equals $D \div d$. Then the lift may be determined as follows: *Flat-seated Valves:* If $r = 1$, the lift $= D \times 0.25$; if $r = 1.25$, lift $= D \times 0.160$; if $r = 1.5$, lift $= D \times 0.111$; if $r = 2$, lift $= D \times 0.162$; if $r = 2.5$, lift $= D \times 0.040$. *Cone-seated Valves of 45-Degree Angle:* If $r = 1$, lift $= D \times 0.307$; if $r = 1.25$, lift $= D \times 0.205$; if $r = 1.5$, lift $= D \times 0.146$; if $r = 2$, lift $= D \times 0.084$; if $r = 2.5$, lift $= D \times 0.055$. Since flat-seated valves generally introduce a certain amount of wire drawing of the incoming charge, a slight increase over the theoretically correct lift should be provided. This allowance seldom exceeds 25 per cent of the theoretical lift.

PORCELAIN. Porcelain is an insulating material of exceptional value. Probably more of this material is used yearly than of all the other insulating materials combined, with the exception of rubber. The characteristics that give porcelain its value to the electrical industry are as follows: High insulating value; a vitrified structure which resists the entrance of water or moisture; refractoriness; resistance to oils and vapors; freedom from tendency to warp, weaken or deteriorate in any way with age or severe service conditions; attractive appearance; ease of forming into various intricate shapes which are made permanent by firing; mechanical strength, with the exception of resistance to impact; and comparative cheapness.

PORT. A port as the term is applied to mechanical devices, is a passageway as in a cylinder or valve. In a steam engine or air compressor, the ports are the openings for the inlet or exhaust of the steam or air. The port for the inlet in a steam engine is known as the steam port and that for the outlet as the exhaust port. In an air compressor, the port for the inlet is known as the inlet port and the port for the outlet as the discharge port.

PORTABLE DRILLS. See Drills, Portable Air-driven; and Drills, Portable Electric.

PORTLAND CEMENT. Portland cement is a chemical compound of lime and silica and lime and alumina, which combines with water when

mixed with it, forming substances of great mechanical strength capable of adhering firmly to stone and sand and, hence, forming a valuable building material. The specific gravity is about 3.1. A satisfactory Portland cement when mixed with water will not develop an initial set in less than thirty minutes, and will not develop a hard set in less than an hour, but it must set hard in less than ten hours.

POSITIVE BLOWER. This is a blower for producing a high positive air pressure for cupola furnaces, gas and oil burners, and other purposes. It is the same as Rotary Blower.

POSITIVE CLUTCH. This is a clutch for transmitting power between two machine members, the driving and driven members of which are connected by the engagement of interlocking teeth or projecting lugs, so that there is no slippage, the power being transmitted in a positive manner. This type of clutch is employed when a sudden starting action is not objectionable, and when the inertia of the driven parts is relatively small. The teeth of positive clutches are made in a number of different shapes, according to the service for which they are required.

POT ANNEALING FURNACE. This is a furnace used, in connection with the production of cold-rolled sheet steel, for annealing the coils of sheet metal. The coils are placed in clay pots and packed with fine iron borings, after which a cover is put on the pot and the joints sealed with fireclay. The pot with the steel is then heated in the furnace for about six hours, after which it is withdrawn and allowed to stand for sufficient length of time to become quite cool before the cover is taken off.

POTASSIUM. Potassium is a metallic chemical element, the symbol of which is K, and the atomic weight, 39.10. Pure potassium is a white metal of silvery appearance, having a slightly bluish tint. It combines rapidly with the oxygen in the air, and is at once covered with a film of oxide, if exposed to the atmosphere. Absolutely dry oxygen, however, has no action upon it. At a temperature below 32 degrees F., the metal is fairly hard and brittle, but at ordinary room temperature it is so soft that it can be cut with a knife. Its specific gravity is 0.87 (its weight per cubic inch being 0.031 pound). It is the lightest metal known, with the exception of lithium. It melts at a temperature of 62 degrees C. (144 degrees F.), and boils at a temperature of 667 degrees C. (1233 degrees F.). Its specific heat is 0.166 at 32 degrees F., and its electrical conductivity (silver = 100) is 19.62. Potassium is the basis of all potash salts or compounds. Combined with oxygen, it forms potassium oxide (K_2O), commonly known as "potash."

POTASSIUM CYANIDE. See Cyanide.

POTENTIAL ENERGY. Potential or stored energy may be defined as stored-up capacity for performing work. It is measured in the same units as work; that is, in foot-pounds. Potential energy is exemplified in the case of a body of water stored in a reservoir, which would be capable of doing work if released and applied to a turbine. The measure of potential energy is obtained by multiplying the weight of the stored body by the distance through which it would fall. Potential energy is used in distinction to *actual* or *kinetic* energy, which is the energy of a moving body and is capable of performing work against a retarding resistance.

POTENTIOMETER. The type of pyrometer known as a potentiometer differs from the millivoltmeter type in that the indicating instrument operates upon a different principle. Instead of utilizing the current to displace either a suspended or pivoted part, the electromotive force of the thermo-couple is opposed by an electromotive force of known value usually derived from a dry cell contained in the instrument. When the balance between the opposing forces is complete, a galvanometer is used to show that no current is flowing, and then the electromotive force of the thermo-couple is indicated directly by the position of a movable contact. The potentiometer requires some outside source of current, but it gives accurate readings and is not affected by resistance changes in the thermo-couple circuit. The meter or indicating instrument of a pyrometer, either of the millivoltmeter or potentiometer types, may either be arranged to show the temperature at any time by a graduated scale and pointer, or may be designed to trace a record of temperature changes upon a chart.

POUNDAL. The expression "poundal" is sometimes used in connection with calculations in mechanics. Many mechanical handbooks, however, do not define it, because of its limited use. A poundal is a unit of force, and is defined as that force which, acting on a mass of one pound for one second, produces a velocity of one foot per second. A foot-poundal is a unit of energy equal to the energy resulting when a force of one poundal acts through a distance of one foot. In order to reduce foot-poundals to foot-pounds, multiply the number of foot-poundals by 0.03108. Dividing the number of foot-poundals by 32.16 (acceleration due to gravity) will also give foot-pounds.

POUND-FOOT. Torque or turning moment, should be expressed as pound-feet or pound-inches, instead of using the term foot-pounds or inch-pounds. Since the foot-pound is the unit of work and is used in horsepower calculations, it is considered preferable to reverse it and use the term pound-foot to indicate torque or turning moment. The reversal of these terms serves to distinguish readily the two units of measurement — the unit of work and the unit of turning moment. The latter ordinarily is

expressed as pound-inches instead of pound-feet, because the dimensions of shafts and other machine parts ordinarily are given in inches.

POUNDS PER SQUARE INCH. The pressure of steam, air, water or any gases or fluids, is given ordinarily in relation to the square inch. 1 pound per square inch = 144 pounds per square foot = 0.0703 kilogram per square centimeter = 2.31 feet of water at 62° F. = 27.7 inches of water at 62° F. = 2.042 inches of mercury at 62° F. = 0.068 atmosphere.

POWER. Power, in mechanics, is *the product of force by distance divided by time*, or the performance of a given amount of work in a given time. Power is measured in inch-pounds per minute or second, foot-pounds per minute or second, etc. The term *power* is frequently used by writers on mechanics to designate a *force*. In connection with the so-called *mechanical powers* — the lever, wheel and axle, wedge, screw, etc. — the applied force is frequently spoken of as the power. This is, however, not strictly correct, as power should always, in mechanics, be used in accordance with the definition given. *Horsepower* is the unit of power adopted for engineering work, and equals 33,000 foot-pounds per minute. See Horsepower.

POWER AND HEAT EQUIVALENTS. One *horsepower-hour* = 0.746 kilowatt-hour = 1,980,000 foot-pounds = 2550 B.T.U. (British thermal units) = 2.64 pounds of water evaporated at 212° F. = 17 pounds of water raised from 62° to 212° F.

One *kilowatt-hour* = 1000 watt-hours = 1.34 horsepower-hour = 2,653,-200 foot-pounds = 3,600,000 joules = 3420 B.T.U. = 3.54 pounds of water evaporated at 212° F. = 22.8 pounds of water raised from 62° to 212° F.

One *horsepower* = 746 watts = 0.746 kilowatt = 33,000 foot-pounds per minute = 550 foot-pounds per second = 2550 B.T.U. per hour = 42.5 B.T.U. per minute = 0.71 B.T.U. per second = 2.64 pounds of water evaporated per hour at 212° F.

One *kilowatt* = 1000 watts = 1.34 horsepower = 2,653,200 foot-pounds per hour = 44,220 foot-pounds per minute = 737 foot-pounds per second = 3420 B.T.U. per hour = 57 B.T.U. per minute = 0.95 B.T.U. per second = 3.54 pounds of water evaporated per hour at 212° F.

One *watt* = 1 joule per second = 0.00134 horsepower = 0.001 kilowatt = 3.42 B.T.U. per hour = 44.22 foot-pounds per minute = 0.74 foot-pound per second = 0.0035 pound of water evaporated per hour at 212° F.

One B.T.U. (*British thermal unit*) = 1052 watt-seconds = 778 foot-pounds = 0.252 calorie = 0.000292 kilowatt-hour = 0.000391 horsepower-hour = 0.00104 pound of water evaporated at 212° F.

One *foot-pound* = 1.36 joule = 0.000000377 kilowatt-hour = 0.00129 B.T.U. = 0.0000005 horsepower-hour.

One *joule* = 1 watt-second = 0.000000278 kilowatt-hour = 0.00095 B.T.U. = 0.74 foot-pound.

POWER FACTOR. In an alternating-current circuit, the electromotive force and the current may or may not be in phase, and the difference in phase determines the "power factor." The power factor is the ratio of the real power to the apparent power. This ratio is generally less than 1, and can never be greater. When the current leads the electromotive force, the power factor is not greater than unity, but is distinguished from that caused by lagging current by calling it "leading" power factor.

POWER HAMMERS. See Hammers, Forging.

POWER OF A NUMBER. Power, in mathematics, indicates the number of times that a certain quantity is repeated as a factor. For example, the *third power* of 5 equals $5 \times 5 \times 5 = 125$. The *fifth power* of 2 equals $2 \times 2 \times 2 \times 2 \times 2 = 32$. The power is designated by an *exponent;* thus the third power of 5 is written "5^3," and the fifth power of 2 is written "2^5." The small figure in the upper right-hand corner of the expression is known as *exponent.*

POWER PLANT EFFICIENCY. The efficiency of a steam power plant, even when it consists of the best modern equpipment, is relatively low. Good boilers impart to the steam, on an average, 70 per cent of the heat of the fuel, or produce, approximately, 10 pounds of steam per pound of good coal used, and less in the case of a poorer grade of coal. Well-designed engines exhausting to the atmosphere use from 30 to 40 pounds of steam per hour per horsepower, so that such boilers and engines working together would require from 3 to 4 pounds of coal per hour per horsepower, and when the power plant is small and the equipment is not of such high grade, the coal consumption may be increased to 6 or 8 pounds. A coal consumption of 3 pounds per hour for each horsepower corresponds to a plant efficiency of about 5.6 per cent, and a coal consumption of 8 pounds, to a plant efficiency of 2.1 per cent. Therefore, non-condensing steam plants equipped with engines of the simple type and burning from 3 to 8 pounds of coal per hour per horsepower are capable of converting into useful work only 5 or 2 per cent of the heat the coal contains. Improvements in equipment and methods of working have increased this value to about 15 per cent in the best modern power plants. This increase in efficiency has been obtained partly by the reduction of heat losses in generating the steam, and the return to the boiler of some of the waste heat.

POWER PRESSES. In order to handle the wide range of work now done by means of dies, many different types of power presses are required. These presses, like the dies used in them, are difficult to classify because of

the variety of designs and the different features which may properly be considered in making the classification. The names commonly given presses by manufacturers indicate, in some cases, the class of work for which the press is intended; whereas the names applied to other types are derived from the constructional features. As examples of names which indicate the nature of the work for which the press was designed, there are drawing, embossing, trimming, punching, forging, wiring, and perforating presses, etc. The construction of presses for these different classes of work varies considerably, there being single-action, double-action, triple-action, multiple-crank, cam, knuckle-joint, and toggle presses. As is apparent, these names are based on constructional features and indicate particularly the nature of the mechanism which operates the slide or ram of the press. Presses are still further classified according to the design of the frames, as indicated by the names inclinable, straight-sided, arch, gap, adjustable-bed presses, etc. In many cases, the names previously referred to are combined, whereas, in others, they are not. For instance, the names inclinable press, straight-sided press, arch press, double-crank press, etc., are commonly used and simply refer to constructional features, whereas combination names, such as toggle-drawing press, knuckle-joint embossing press, straight-sided trimming press, etc., suggest the general nature of the work for which the press is intended, as well as some important constructional feature. While power presses are made in an almost endless variety of designs, there are, however, certain types which might be considered standard, although different makes vary more or less in regard to constructional details. See Double-action Presses; Embossing and Coining Presses; Friction-driven Screw Press; Gang Presses; Inclinable Power Presses; Knuckle-joint Embossing Press; Multiple-crank Presses; Straight-sided Power Presses; Stagger-feed Press.

POWER PRESS FEED MECHANISMS. When mechanical feeds on power presses are warranted by a reasonably large production or by the character of the work, they effect economies by increasing the normal production rate or decreasing the labor cost, or by a combination of both. The type of press, the length of stroke, and the work to be handled all affect the speed of hand feeding. Obviously, strip stock which does not have to be accurately located can be fed very rapidly by hand, and on such work there might be little economy in equipping presses running at less than 30 to 40 strokes a minute with mechanical feeds. Work requiring to be located more accurately, however, or parts that are hard to place correctly in the die, may be fed mechanically to advantage, even at much lower speeds. The increase in production effected by mechanical feeding may be due to speeding up the press or to the fact that the feed " catches " every stroke with the press running continuously, while without a feed,

the operator may have to trip each time or he may require that the press be run more slowly to feed every stroke.

Driving Mechanical Feeds. — The matter of driving and timing mechanical feeds properly is a problem in selecting the most suitable driving method and so arranging it as to make the most of the available time in the cycle and to get the smoothest action. Smooth action, uniform acceleration and deceleration, and the design of parts so that the possibility of wear and backlash occurring is reduced to a minimum are essential in securing and maintaining accuracy and reliability. Most press-feeding involves one uniform motion, in the same direction, at each stroke of the press. In the majority of cases, this is derived from a crank or a cam on the free protruding end of the press crankshaft, although in some cases sprockets, gears, etc., are used in connection with clutches, grippers, or friction devices. In general, where there is a choice, a crank motion is decidedly preferable to a cam motion, because it can be run faster, is easier to adjust and maintain, and is much cheaper to construct.

Arc for Feed Motion. — The working portion of the stroke on single-action crank presses is considered in most cases to be up to half (the lower half) of the down stroke or from 90 degrees to 180 degrees (nearly) as the shaft revolves. If all of this is used, then another full quarter turn will be required on the up stroke to bring the punch clear. This leaves a full half turn (180 degrees), from 270 to 90 degrees, for feeding. If a straight crank motion is used, it requires this remaining 180 degrees for the feed stroke. The feed is usually arranged on the up stroke of the crank-pin to bring the connecting-rods into tension while feeding. A simple crank-driven feed motion, with the feed crankpin 90 degrees in advance of the press crankpin, brings the feeding action on the up stroke and, provided the connecting-rod works vertically, the feed begins at 270 degrees and finishes at 90 degrees. This drive is suitable for dial or roll feeds and the like, provided the working portion of the stroke is completed and the punches are clear again in less than 180 degrees. This is necessary because the dial or strip material passes under the punches in feeding, and obviously, there must be no interference.

The crank-driven feed motion with the feed crankpin advanced 180 degrees ahead of the press crankpin, is suitable for some magazine feeds and special push feeds, where the first part of the feed stroke is to pick up a slug from a stack, and the last part (90 degrees or less) is to deliver it to the die, or where a portion of the feed mechanism must cross the die and return it in locating the work. For the first case, this timing has the advantage that the feed is completed before the stopping position of the press is reached — a favorable point when setting up and adjusting.

Double-action presses in general, and single-action presses in some cases,

are not suited to the plain crank drive on account of not having a full half cycle (180 degrees) available for the feed action. This applies only, of course, to roll and dial feeds and the like, in which the work or the feed itself travels under the punches through the whole feeding stroke. Double-action toggle presses are usually stopped about 15 degrees ahead of top center, as this is the highest point reached simultaneously by both slides. The blank-holder dwell is arranged to start before the punch reaches the material, and to hold until about 10 degrees after the draw is completed. There remains about 135 degrees during which the work space is clear for feeding.

POWER PRESS INDEXING FEEDS. Feeds designed to grip and advance or rotate strip, circular, cylindrical, or conical shaped work for a series of punching, notching, perforating, or stamping operations, equally spaced, usually require special treatment to suit the particular job. Specific applications include, for instance, feeds for use in perforating cylindrical or conical shapes, armature disk notching, silver-plate decorating, flat perforating, etc. The essential features common to most of these feeds are means of locating the work accurately; means of gripping it securely; feeding motion (usually a ratchet type, crankdriven); and a device to stop the press after the desired number of strokes. Also in most cases, there must be means of stopping the press at any time and, especially for flat work, a cam stripper to reduce distortion to a minimum. Convenience of arrangement and accuracy are essential to all feeds. Indexing feeds in general are not adaptable to standardization, on account of the wide variation in the work to be handled and in the types of presses they are applied to. However, all have the same general characteristics of advancing and rotating the work a fixed amount for a predetermined number of strokes, and then stopping the press, and therefore make use of similar motions and devices.

POWER PRESS MAGAZINE FEEDS. Magazine feeds, which in some cases are also called coin feeds and tube feeds, are a comparatively simple type, adapted to handling blanks of sufficient thickness to permit of being fed out positively from the bottom of a stack. They are also used in some cases for such stampings or forgings as can be stacked without danger of nesting or interlocking and are not so high as to be in danger of toppling over. This type of feed can usually be built as an entirely self-contained unit, which may be bolted to the press bolster. It may be placed either at the front or the side of the press, and can be applied to practically any type of press. Placing the feed at the side is usually the most satisfactory for end-wheel type gap-frame presses, on account of the drive, but for the side-wheel type presses, it may be mounted either at the front or the side,

according to the conditions of the individual case. Adjustment can be provided on the driving crankpin to alter the length of the feed stroke, but as this is rarely necessary, a fixed crankpin is more usual.

Magazine feeds for press work are used particularly in connection with coining, swaging, piercing, and forming operations, and on some stamping and repunching work. These feeds are sometimes used in connection with hopper feeds, which are rather complicated. Another modification includes the use of gripper fingers on the reciprocating slide, in which case the blank is dropped into the die centrally, instead of being pushed into it. It is often possible, when magazine feeds are being used, to utilize some sort of stacking device under the press, to receive the blanks and facilitate feeding.

Gravity Chute Feeds. — Gravity chute feeds are comparatively simple, consisting only of a chute of proper dimensions, down which the work moves by gravity, and a releasing device to drop one piece at a time into the die, with sometimes the addition of a mechanism to gage and hold the shell in the proper position. The presses are usually used either in the horizontal position on special legs or inclined back 45 degrees or more from the vertical. This method of feeding is limited to parts that can be put into a chute without danger of becoming twisted or of overlapping. Gravity chute feeds are also used on automatic machines for rolling beads and threads, or similar work.

Hopper Feeds. — On some classes of work, where small partially worked symmetrical parts are fed in large quantities to fast presses, hopper feeds are advisable. They include a hopper, or receiver, in which the pieces are agitated, and those that fall in the right position are passed on, timed, and carried by some one of the simpler feed motions into the die. Hopper feeds for screw blanks or parts that can be picked up by the head, are more or less standardized, and are quite well known. Hopper feeds for press work, however, present a more serious problem, on account of irregularities in the parts and the dangers of injury, jamming, and misfeeding. The development cost is necessarily high, as each feed presents a problem in itself, and frequently requires some novel solution.

POWER PRESS RATCHET DIAL FEEDS. Ratchet or station dial feeds consist essentially of a dial having stations to hold the work being operated on, and driven from the press shaft by a suitable ratchet mechanism, so that the stations are brought successively, accurately and positively under the punch. The drive may be from the simple crank disk on the end of the shaft, although in some cases, it is necessary to use a cam drive or scotch-yoke drive where less than 180 degrees is available for feeding. The dials are of two general classes — those having a locating bushing in each station on the dial to carry the work into alignment over a die in the

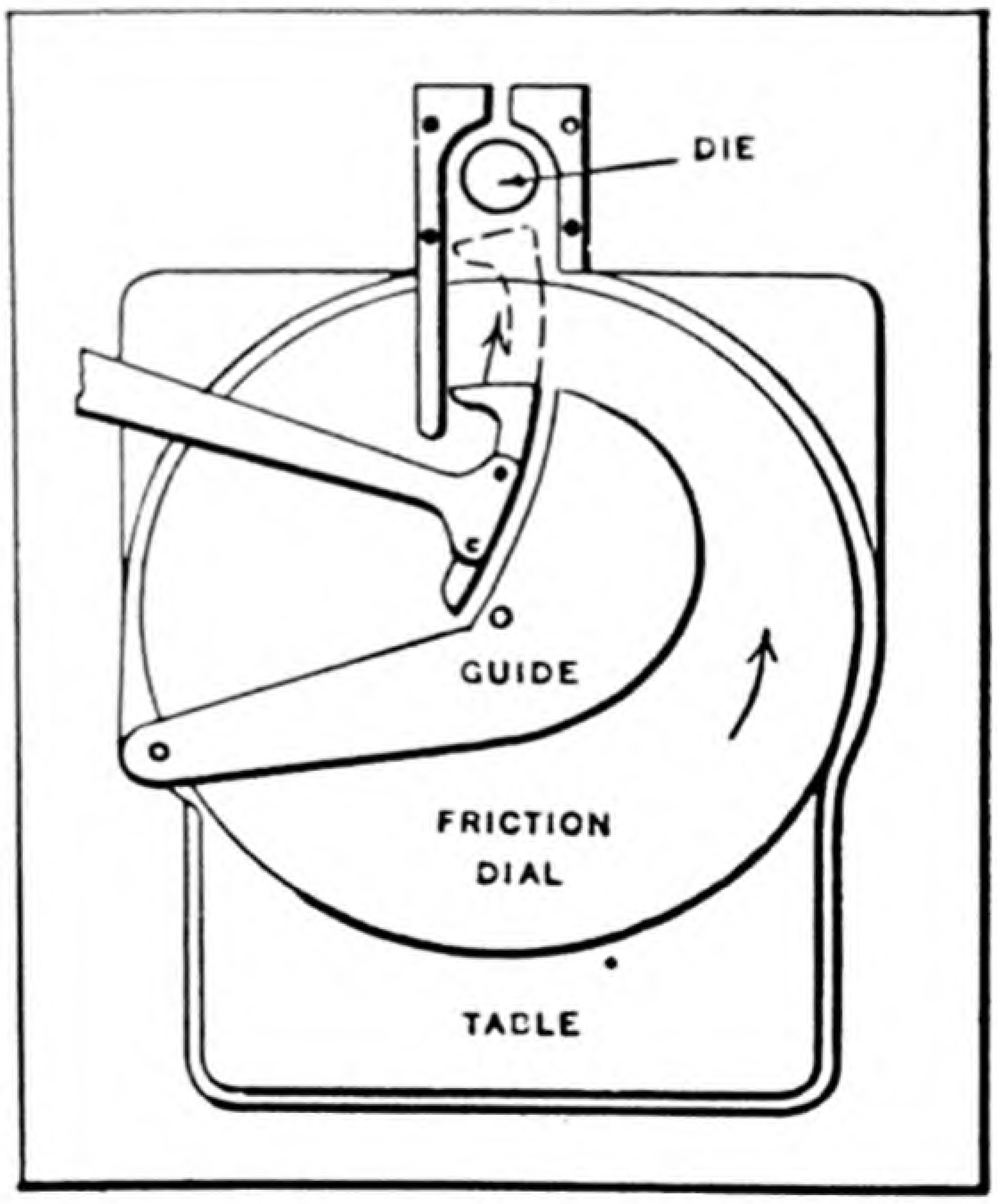
bolster below the dial; and those having a complete die at each station on the dial.

Obviously, the structural requirements of this type of feed are that the dial shall move smoothly and accurately, that the notches and stations shall all be very accurately located and machined so that the work will be properly aligned with the punch every time, that the feed motion shall function accurately and reliably, and that lost motion and the opportunity for wear shall be reduced to a minimum. Dial bushings or dies must be interchangeable. The class of machine work required on a dial feed is very high.

These station dial feeds are adapted especially to handling work for secondary operations, such as redrawing, piercing, stamping, broaching, wiring, punching, and burring. Sometimes it is possible to perform two or three operations in sequence at successive stations. In such cases, it is advisable to balance the operation so that the strain on the slide will not be much off center, and to provide separate adjustments for height on the punches. Feeds of this type are also used for assembling, riveting, and closing operations on finished parts and on material other than metal.

As these feeds are ordinarily arranged, the operator places the work in the bushings or on the posts at the front of the dial, from which point they are carried around into the working position and then ejected. An unskilled operator can catch every stroke of a press that is operating at full speed, and can accomplish this without any danger of losing a hand.

Friction Dial Feeds. — The accompanying illustration represents diagrammatically a plan of a typical friction dial feed. This is a comparatively simple type of feed consisting, as a rule, of a table, a revolving friction disk on which are suitable guides, and a lateral feed or escapement. The operator has only to push the shells from the table to the disk, right side up. The combination of the friction drive and the guides lines them up and the escapement feeds the pieces one at a time into the die or series of dies. This type of feeding mechanism is suited especially to handling parts (usually drawn shells) that have their center of gravity low enough so that they are not likely to tip over.



Plan of Typical Friction Dial Feed

POWER PRESS ROLL FEEDS. Roll feeds, suited to feeding strip or ribbon stock by means of intermittently driven rolls, are quite universal in their range of work, when properly designed, and are readily adaptable to standardization, when they are built in sufficient quantity. The whole feed can be built as a self-contained unit on a bolster plate, with merely a driving collar or arm for the end of the shaft. Roll feeds may be arranged to operate either front and back or right and left (the most common method) on gap-frame presses, and front and back on straight-sided presses or right and left on such presses when arrangement can be made to feed through an opening in the housing.

Single roll feeds are those having only one pair of rolls at one end of the bolster, adapted either to pushing across the die, stock that is sufficiently stiff to preclude the chance of buckling, or to pulling the strip across by the scrap, where the scrap is strong enough not to break and is not too deformed. Double-roll feeds are built with a pair of rolls at each end of the bolster, so that the pulling stress on the stock is somewhat distributed and the material between the rolls is kept taut, preventing wrinkling or buckling; they are therefore suited especially to very thin or narrow material or to material lacking stiffness and body, though they are often used with heavier materials for control at start and end. Double-roll feeds are very similar to the single-roll type, requiring merely the addition of a practically identical housing and pair of rolls. For short feeds, the second pair of rolls is provided with another friction device, which is driven from the first pair by the reciprocating motion of a connecting cross-bar. When the feed exceeds 90 or 100 degrees on the rolls, bevel gears and a connecting-shaft are used.

The length of the feed is governed by the diameter of the rolls and by the arrangement. The direct-connected feed is limited to a maximum feeding arc of about 100 degrees. Longer feed strokes are obtained by the use of a rack connected with the crank block and driving a gear having the friction grip device built into it. For an accurate feed, especially of the friction type, there should be the least possible opportunity for backlash between the friction device or ratchet and the rolls.

There are various accessory attachments used occasionally with roll feeds to suit special conditions. These include strip oiling and straightening devices and scrap-cutting shears or scrap-winding reels. Scrap-winding devices coil up the scrap material so as to make subsequent handling easy. Another method with a similar object is to provide a small gate shear driven from the slide or shaft of the press to cut off a portion of the scrap at each stroke, so that it falls into a barrel or tote box and no rehandling is necessary.

POWER PRESS SAFEGUARDS. To prevent power-press accidents, the hands of the operator should be kept from under the ram when it descends,

by means of mechanical safeguards put on the machines for this purpose. Four methods by which this can be done are as follows: 1. By having a guard which pushes the hand away before the ram descends. 2. By having a device which prevents the clutch being thrown, locking the ram in its upper position while the operator's hands are under the ram, but releasing it when the hands are removed. 3. By having a guard entirely surrounding the danger zone. 4. By requiring both hands to be used to operate the machine. The machines which are operated by the foot will require guards of the first, second, or third classes, as the hands will be free to get in the way of the descending ram. A machine so designed as to require the use of both hands to operate it is a safety device in itself; but if only one hand is required, then it would be advisable to adopt one of the other three methods. A guard should not hinder the workman, and it should be so attached to the machine that it cannot readily be removed and discarded.

POWER PRESS SELECTION. In selecting a press, there are a number of factors to be considered. These include type of frame, power, speed, and stroke. Gap (or cut-back) frame presses lend themselves most readily to the application of feeds, and the inclinable feature on some types is of value to effect gravity discharge from the die. Arch-frame and straight-sided frame presses are not so convenient for the arrangement of all types of feeds, but have the advantage of straight-frame spring only, or still less spring in the case of built-up frame presses properly assembled.

Gap-frame presses will spring on an arc about in proportion to the load. The effect of this spring in presses that have not been selected with sufficient care is to cause a less distinct impression at the front in stamping work, and a tendency to wear, especially at the front and back in blanking dies — particularly in those in which there is very little clearance between the punch and die. It was demonstrated in one case, for instance, that the life of expensive dies was increased from about 15,000 punchings per grind to 250,000 by changing to a heavier and stiffer press, although the original press appeared to be handling the work with ease.

The required strength of the press frame and shaft depends upon the load or pressure to be exerted. The power requirement governing flywheel, gearing, and motor depends upon the stroke and work; that is, the energy to be delivered is the product of the pressure and the distance through which it must act. Thus for short-stroke blanking work, a flywheel press is usually sufficient, but for long-stroke drawing or forming work requiring the same pressure but exerted through a longer distance, a geared press is necessary, as its flywheel runs proportionately much faster and makes available more energy for the same percentage of speed reduction.

During the short portion of the stroke in which the actual work is done, the motor is called on to stand an instantaneous overload of 50 to 75 per cent

and a speed reduction of 10 to 20 per cent. It is the flywheel and not the motor, however, which supplies the bulk of the energy to perform the work, and the chief function of the motor is to restore the lost energy (and speed) to the flywheel during the idle time between working periods. It is evident that a press may have sufficient power to "pull" a given job when the press is tripped each stroke and the recuperating period between strokes is long; but when the same press on the same job is fitted with a mechanical feed catching every stroke, the power demand comes oftener, and the recuperating period is shorter, so that more power is demanded of the motor, and a larger motor may be required.

POWER PRESS STOP MECHANISM. See "Beaver-tail" Stop.

POWER PRESS TONNAGE. The method of rating power presses varies considerably among different manufacturers. Some rate their presses by number, the number used bearing a certain relation to the diameter of the crankpin. For instance, when a flywheel press has a crankpin, say, 5 inches in diameter, the rated capacity may be the square of the diameter, or 25 tons pressure. The number given to a press, however, does not always indicate its capacity, which may depend, to a certain extent, upon the gearing. Other manufacturers use the diameter of the flywheel and its maximum velocity as a basis upon which to rate the capacity of the press. Another method is to calculate the diameter of the crankpin in practically the same manner as a beam supported at both ends, the cross-section of the crankpin being determined by what the tonnage would be at the dead point. In other words, the dead-point tonnage is used to indicate the tonnage of the press. By this method, however, the tonnage has no direct relation to the number given, which is chosen arbitrarily. According to another method, the nominal capacity of the press in tons is equal to three and one-half times the square of the diameter of the crankpin. For instance, a press having a 2-inch diameter crankpin would exert a pressure of 14 tons. The nominal tonnage of a press may also be related to the strength of the frame and crankshaft, and establishes a standard stroke; any increase in the stroke changing the capacity of the press.

The following empirical rules, for computing the tonnage by the weight of the press, depend for their usefulness on the presses to which they are applied but these rules conform closely to designs that have given general satisfaction in use. In the case of most straight-side or pillar presses the weight of the press in pounds divided by 80 will give the capacity of the press in tons. On overhanging presses of ordinary design the weight of the press should be divided by 100 to 120 to obtain the tonnage. For example, the tonnage of a straight-side press weighing 5600 pounds is $5600 \div 80 = 70$ tons, which is approximately correct. In the case of an

overhanging press weighing, say, 3200 pounds, with an average depth of throat of about 7 inches, we have $3200 \div 100 = 32$ tons capacity, which also is close to the correct figure. On small overhanging presses the weight of the flywheel divided by 16 gives the tonnage of the press closely, but on large presses weighing 2500 pounds or more, the weight of the flywheel is divided by 20 in order to get the approximate tonnage.

POZZUOLANIC CEMENT. Pozzuolanic (or Puzzolan) cement, also known as *slag cement*, is a finely pulverized product obtained by making a mechanical mixture of granulated basic blast furnace slag and hydrated lime, this mixture being ground to obtain the cement. The blast furnace slag is granulated by being run into water while in a fused condition. The usual proportions in the mixture are three parts of slag to one part of slaked lime, by weight. Slag cement is not as strong, uniform, or as reliable as Portland or natural cements, and should be used only for foundation work under ground, where it is not exposed to air or running water. It sets slowly, but its strength increases considerably with age. Although it is a cheap material, suitable for many purposes, it is not largely used.

PRECIPITATION. In chemistry, precipitation is the process of separating a substance from a solution by adding another substance to the solution. The separated substance is known as the *precipitate*, and the substance which is added to cause the precipitation is known as the *precipitant*.

PRECISION LATHE. See Lathe Classification.

PREFERRED NUMBERS. The term "preferred numbers" has been applied to series of numbers representing geometrical progressions but based upon *preferred* factors or ratios which are certain roots of 10. The ratio of progression, informally approved by the American Engineering Standards Committee and recommended to industry for a period of trial in practice is either the fifth, tenth, twentieth, or fortieth, root of 10. This system has been proposed as a universal standard for use whenever a series of sizes or values is required, as in the manufacture or design of tools, products, or machines intended for general application in the mechanical industries.

The purpose of a system of preferred numbers is to eliminate the economic loss involved in the haphazard and often needlessly numerous gradations of size that characterize many common commodities. Preferred numbers are valuable to every industry concerned with manufacturing or purchasing according to definite series of sizes. The fundamental elements of the system lie in the proposal to arrange standard size series so that each succeeding model in a series shall be larger than the preceding size, not by a

definite amount, but by a fixed percentage. By decreasing the number of sizes within a certain range while retaining a sufficient number of sizes in all parts of the range, a system of preferred numbers makes it possible to effect savings in materials, labor, storage space, gages, containers, catalogs, sales cost, etc.

Assume, for example, that the preferred numbers or sizes are based on the fifth root of 10 ($\sqrt[5]{10}$) or the "5 series"; then the numbers in a 1 to 10 range would be 1–1.6–2.5–4–6.4–10. In the 10 series the numbers would be 1–1.25–1.6–2–2.5, etc. In the 20 series the numbers would be 1–1.12–1.25–1.4–1.6, etc. In all length measurements the numbers apply to the inch as the unit of length. With all other measurements than lengths, the numbers apply to the unit forming the basis of the standardization. The numbers of the 5 series (fifth root of 10) are recommended in preference to those of the 10 series, and these in preference to the 20 series and these in preference to the 40 series. Numbers, however, may pass from one series to an adjacent series.

To illustrate the importance of preferred numbers a change of $\frac{1}{4}$ inch in width would be important in a brush $\frac{1}{2}$ inch wide, while in a brush 5 inches wide a change of $\frac{1}{4}$ inch would be hardly discernible. Instead of having quarter inch increases throughout the whole range of sizes, therefore, sizes can be increased by a fixed percentage without eliminating any which are necessary, and decreasing the total number. Thus, if the next size above one inch is $1\frac{1}{4}$ inches, the next size above 4 inches would be 5 inches instead of $4\frac{1}{4}$ inches.

An example of increase by a fixed percentage rather than by a definite amount is found in the American or Brown and Sharpe Wire Gage, which has been in successful and wide use since 1857. Preferred numbers have been used with success in many European countries, including France and Germany.

PREMIUM WAGE SYSTEM. There is some similarity between the premium wage-paying system and the *differential wage system*. The difference between the two systems is that, in the premium plan, the increased pay is based upon the *time saved* instead of upon an increase in the piece rate. The standard of efficiency is fixed by determining upon a reasonable time in which the work can be completed. If the workman completes the work in a shorter time, he receives his regular hourly rate for the time that he has worked upon the job, and, in addition, he receives a premium for having worked faster than the standard requirements, this premium consisting of from 25 to 50 per cent of the difference between the wages earned in the shorter time and the wages that would have been paid if the job had been done in the fixed standard time. A minimum wage is generally incorporated in this system, so that the workman is always insured of a

certain amount of pay in case he is not able to earn a premium. See Wage System, Premium.

PRESENT VALUE. In the appraisal of manufacturing plants, the value of equipment at the time of the appraisal is known as the "present value." It equals the *replacement value* less the accrued *depreciation* at the time of the appraisal.

PRESSED FITS. See Forced Fits.

PRESSED STEEL. The term "pressed steel" is commonly applied to parts made from sheet steel by the die and press method. Pressed-steel parts have been used in many lines of manufacture to replace castings, forgings, and machined parts. The advantages of using pressed-steel parts often include such factors as reduction in weight and accompanying reduction in cost of raw materials and transportation charges for finished products; increased strength, as compared with replaced parts; larger production; and improved appearance of finished parts.

PRESSES. See Drop Presses; Hydraulic Presses; Power Presses.

PRESSURE, ABSOLUTE AND GAGE. See Absolute and Gage Pressure.

PRESSURE ANGLE OF GEARING. A line drawn tangent to the two base circles of intermeshing spur gears is known as the *line of action*, because the point of contact between two gear teeth having involute curvature is along this line as the teeth roll in mesh with each other. This line of action may be represented by a crossed belt, if the base circles are considered as pulleys connected by such a belt. The angle between this line of action and a line perpendicular to the center line of the two gears, is known as the *pressure angle* of the gearing. Gearing is commonly designated by giving the pressure angle. For instance, the expression 14½ degrees, 20 degrees, etc., as applied to gearing, relates to the pressure angle of the gearing.

In the design and manufacture of gearing, certain pitches, pressure angles and tooth proportions have been used so extensively that they are generally accepted as standards. While 14½ degrees is the most common pressure angle, as applied to miscellaneous classes of gearing, 20 degrees may be regarded as the standard sanctioned by common usage for certain types of transmission gears, and herringbone gears usually have an angle of 23 degrees. Bevel gears, as well as spur gears, are designed for both 14½- and 20-degree pressure angles, and other angles are employed, although not very extensively at the present time. A 14½-degree angle is unsatisfactory for exceptionally small gears (especially if the teeth are of standard or ordinary proportions) because of under-cutting which weakens the teeth and

causes poor tooth action when two gears revolve together. For information concerning the reasons why $14\frac{1}{2}$ degrees was selected as a pressure angle see Gear Teeth, Historical Notes.

PRESSURE, ATMOSPHERIC. See Atmospheric Pressure.

PRESSURE ATTACHMENTS FOR DRAWING DIES. In the application of drawing dies for drawing hollow parts of various shapes, it is essential to apply enough pressure on the outer surface of the flange or flat blank to prevent the formation of wrinkles. Excessive pressure, however, will unduly strain the material and may result in fracturing it. There are several commercial types of pressure attachments designed to maintain a uniform blank-holder pressure or prevent an increase of pressure as the depth of the "draw" increases. Some of these attachments are equipped with combinations of springs and links and others have pneumatic cushions, the latter often being called die cushions. These modern types of pressure attachments not only improve the drawing operation but reduce the number of operations in many cases and, in addition, they increase the range of work which can be done on single-action presses.

PRESSURE EQUIVALENTS. 1 pound per square inch = 144 pounds per square foot = 0.068 atmosphere = 2.042 inches of mercury at 62 degrees F. = 27.7 inches of water at 62 degrees F. = 2.31 feet of water at 62 degrees F.; 1 atmosphere = 30 inches of mercury at 62 degrees F. = 14.7 pounds per square inch = 2116.3 pounds per square foot = 33.95 feet of water at 62 degrees F.; 1 foot of water at 62 degrees F. = 62.355 pounds per square foot = 0.433 pound per square inch; 1 inch of mercury at 62 degrees F. = 1.132 foot of water = 13.58 inches of water = 0.491 pound per square inch.

PRESSURE FAN. A special form of ordinary ventilating fan. See Fan Blower.

PRESSURE FILTER. See Filters.

PRESSURE HEAD. The pressure against which a pump forces the water is usually expressed in "feet head." For example, a pump feeding a boiler against a pressure of 100 pounds per square inch is operating under a head of $100 \div 0.433 = 231$ feet; that is, each pound pressure per square inch against which the water is forced is equivalent to lifting a column of water 1 inch square and 2.31 feet high. From the above, it is evident that: Pressure per square inch in pounds $\div$ 0.433 = head in feet; head in feet $\times$ 0.433 = pressure per square inch in pounds.

In determining the pressure head or total height to which the water must be raised, the distance must be taken from the surface of the water in the reservoir from which it is drawn to the point of discharge. The same

power is required to raise water by suction as to force it, and the height of the pump above the water does not enter separately into the calculation at all, provided the " lift " is within the maximum limit.

PRESSURE REGULATOR. In air compressors, a pressure regulator is a device which closes the inlet pipe of an air compressor and connects the two ends of the air cylinder, when the receiver pressure reaches the maximum point desired.

PRICKER. Prickers are small projections provided on the outside of a core barrel which serves to hold the green sand or loam when making a large core. Cast core barrels over eight inches in diameter are generally provided with cast prickers placed from 2 to 3 inches apart. Wooden core barrels are provided with nails driven closely all over the exterior surface, serving the same purpose as the cast projections.

PRIMARY AND SECONDARY. The terms " primary " and " secondary " as commonly used in electrical work, serve to distinguish the windings in regard to energy flow, the primary being that which receives the energy from the supply circuit, and the secondary that which receives the energy by induction from the primary.

PRIMARY CELL. A primary cell is any apparatus for transforming chemical energy into electrical energy. A primary cell is frequently termed a primary battery, but the term primary battery properly used refers to the joining of two or more primary cells, which then form a battery. A primary cell generally consists of a liquid known as the electrolyte and two metals called the elements or electrodes. In dry cells, the liquid is replaced by some absorbent material saturated by the electrolyte.

PRIME MOVER. A prime mover may be defined as any machine which, by utilizing some of the forces of nature, produces power for the use of other machinery and devices. The principal prime movers are the steam engine and turbine, the gas and oil engine, the water turbine, and the windmill. The electric motor is not, strictly speaking, a prime mover, as it is driven by current obtained from a generator which, in turn, is driven by a prime mover. A prime mover may be defined briefly as a machine in which a natural form of energy is transformed into mechanical energy. The power from the prime mover is transmitted to the machine in which it is used for producing a given work, by some form of power transmission, which may either be mechanical, hydraulic, pneumatic, or electrical.

PRIME NUMBERS. A prime number is one which is not exactly divisible by any number except itself and 1. Thus, 3, 5, 7, 11, 13, etc., are prime numbers. A factor which is a prime number is called a *prime factor*. Prime numbers play an important part in calculations relating to indexing, gearing

ratios, etc. Tables of prime numbers will be found in mechanical engineering handbooks.

PRIMING. If the steam which is generated in a boiler contains an excessive amount of moisture as it passes into the steam main, this condition is commonly referred to as *priming*. This may be caused by impure water, too high a water-line, the presence of oil, or of certain alkalies used in the removal of scale. Priming may also be caused by forcing a boiler beyond the capacity for which it is designed. When the steam rises from the surface of the water with too high a velocity, it has a tendency to carry more or less spray with it, which, when once in suspension, does not readily settle against a rising current, and thus passes over into the main with the steam.

PRINCIPLE OF ARCHIMEDES. See Buoyancy.

PRISM. A prism is a solid body in which the two end faces are parallel and in which the lines along which all the other faces intersect or meet are parallel. If all the sides of a prism are rectangles and the end faces are either squares or rectangles, the prism is called a *square prism*. In a square prism, the opposite surfaces or faces are parallel and all the angles are right angles.

PRISMATIC BORAX. This is the common form of borax. It is not as suitable for use as a flux in soldering or welding as is jewelers' or octahedral borax, as it does not fuse as readily. See Borax.

PROFILE GRINDING MACHINE. The profile grinding machine is a special type of grinder designed to grind formed turning tools of irregular shape, such as are used for relieving formed milling cutters, etc. In the operation of one design, a master form is attached to one table and the piece to be ground is clamped in a fixed position to another table. The grinding wheel is made to reproduce the outline of the master form by means of a follower pin which is kept in contact with the master form. The radius of the wheel is made to correspond with that of the follower pin by means of a diamond truing device.

PROFILE PAPER. The horizontal ruling on profile paper is usually ten lines to the inch, and the vertical ruling is 20, 25, or 30 lines to the inch. Profile paper is used by civil engineers for representing the profile or cross-section of grades, cuts, embankments, excavations, etc. For the use of railway surveyors, the profile paper is made in continuous strips, folded between covers in book form; these books are called *profile books*. Standard profile paper is obtainable in green and orange ruling, and either in sheets or in rolls. The sizes of the sheets are 15 by 42 inches and the rolls contain 50 yards, 10 or 20 inches wide.

PROFILING MACHINES. A profiling machine or "profiler" is a type of vertical milling machine which is largely used for making parts of guns, pistols, typewriters, sewing machines, and for similar work. Profiling machines are adapted to milling duplicate pieces having an irregular shape or contour, especially in connection with interchangeable manufacture. The distinguishing feature of this type of machine is that the spindle and milling cutter, instead of revolving in a fixed position, are guided by a special former plate, the outline of which exactly corresponds to the shape required on the work. Most of the profilers used at the present time are hand-operated, so far as the feeding movements are concerned. They usually have either one or two cutter spindles, the two-spindle type being commonly used. Each spindle has a former pin which is located a fixed distance from the cutter and is guided around the former plate or model by feeding the cutter-slide and pin laterally and the work-table in a longitudinal direction. By this method, duplicate parts of irregular shape can be produced.

Semi-automatic Profiler. — In armories, etc., where large numbers of irregular-shaped parts must be milled, semi-automatic profiling machines are used to some extent in place of the hand-operated type. The head in which the two cutter spindles are mounted is stationary while the machine is operating, and the required form or contour is obtained by the movement of the table. The latter is carried at the front end of a swinging arm which is journaled in the bed between the uprights, and as the table rotates, it is given an oscillating movement by means of a cam which is attached to it and bears against a stationary roller. This cam, which is located at the base of the work-table, must be made to suit the profile of the parts to be milled. The number of pieces that can be milled at one time depends upon their size and the length of the profile which requires machining. The parts to be milled are held in a special fixture attached to the top of the table, and the cutter passes from one part to the other as the table revolves and is guided by the cam. When the cutter is traversing the spaces between the work, the table speed is automatically accelerated.

PROFIT-SHARING SYSTEMS. The history of profit-sharing has, on the whole, been disappointing. Companies engaged in profit-sharing have been no more free from labor troubles than companies not so engaged. Many firms have given up the idea after a lengthy experience with it. There are some cases in which profit-sharing has been a conspicuous success, but they are few in number. The simplest method of apportioning profits, and one which has often been used, is to pay each employe sharing in the profits the same per cent of his year's wages as is paid to the stockholder in the form of a dividend. Thus, if a 6 per cent dividend is declared on the stock of the concern, every employe participating in the profits

receives at the end of the year an amount equal to 6 per cent of his wages for that year. The division of profits is not necessarily deferred until the end of the year, but may be made quarterly or semi-annually.

A second method of profit-sharing divides the net profits of the business into two equal portions, one going to the stockholders and the other to the employes. The half apportioned to the employes is usually divided in proportion to their earnings. Suppose that a firm having a capital stock of $500,000 has a wage roll of $1,000,000, and that the net profits for the year are $100,000. $50,000 of this is apportioned to capital, and the stockholders receive a dividend of 10 per cent. The other $50,000 is apportioned to labor, the employes receiving a dividend of 5 per cent of their wages.

A third method of profit-sharing is quite different from either of these. It is assumed, first, that labor is entitled to the current wage, and second, that capital is entitled to the current interest rate. After labor has received its wages and capital its interest, a surplus may remain. This surplus is then apportioned between the stockholders and the employes in proportion to their earning power. Thus if the current interest rate is 5 per cent, a man who receives wages amounting to $1000 per year has the same earning power as $20,000 worth of stock. (Strictly speaking, this is not true, if it is considered that a man, like a machine, has a limited life and is, therefore, subject to depreciation. Allowance for depreciation reduces the value of a man's earning power by almost one-third. The introduction of this element of depreciation complicates the matter so greatly, however, that it gives the method an appearance of unfairness in the eyes of the average employe, and is best avoided.) The following case will illustrate the application of this method of profit-sharing. Assume that the wage roll for the year is $1,000,000, that the capital stock is $2,000,000, and that the total profits of the business are $320,000. Labor has already received the current wage. Assuming an interest rate of 5 per cent, the $2,000,000 of capital stock is entitled to $100,000 in interest. The earning power of the employes, *i.e.*, their annual wages capitalized at 5 per cent, is $20,000,000. Adding the earning power of the employes to the amount of the capital stock gives $22,000,000, upon which a dividend of $220,000 will be declared. This amounts to 1 per cent and, accordingly, the stockholder will receive a dividend of 6 per cent upon the par value of the stock, and the workmen will receive a dividend of 1 per cent upon their earning power, which will be 20 per cent of their annual wages.

If the profits realized in different industries were apportioned between capital and labor by any of the three methods which have been outlined, it would be found that, in some industries, the portion available for labor would be exceedingly small, probably only two or three per cent of the annual wage roll. In other industries, the profits would be very great,

sometimes being sufficient to double the employes' incomes. Unfortunately, as a general rule, the profits are the smallest in those industries where the wages are the lowest. There are a few industries of special character or in newly established lines of manufacture where the margin of profits is large, and where it is possible to pay unusual profits to the employes.

PROGRESSION. In mathematics, a progression is a series of numbers which increases or decreases according to some definite law. Arithmetical progression is a series where each term is obtained by adding or subtracting a given quantity to or from the next preceding term. In geometrical progression, each succeeding term is produced by multiplying the preceding term by a given factor.

PROGRESSIVE ASSEMBLY. In their simplest form, conveyor systems merely represent a method of carrying parts to specified points, but in automotive and other large manufacturing plants, the conveyor may also serve many other useful purposes. Important among these is the so-called method of progressive assembly. By this method, a conveyor system travels at a specified speed and carries the work past men who are employed to mount successive parts on the product as it is carried past them by the conveyor. Where the progressive assembling method is employed, various parts to be assembled are delivered at the proper points along the assembling line. The proper conveyor speed is a matter that can only be determined by actual operation. This method of assembling was originated in the automobile industry, and the results obtained were so successful that it has since been adapted to meet the requirements of other lines of manufacturing.

PROGRESSIVE DIES. See Follow Dies.

PROJECTION. Mechanical drawings are based on a method of drawing known as "orthographic projection." In order to illustrate simply this method of drawing, assume that some object is held in the hand on the same level as the eyes and is turned so that the front side, top side, and end are each seen successively. These different views will then correspond practically to the different views of the same object as represented by a mechanical drawing made according to the orthographic projection method. Mechanical drawings composed of views representing different sides of a machine part, tool, or some other mechanical device, show the length, breadth, and thickness of various portions of the piece accurately, which is a great advantage in mechanical work, because the chief purpose of most mechanical drawings is to represent mechanical devices so clearly that they may readily be constructed. An important part of the draftsman's work is to place on the drawing all necessary dimensions expressed either in

feet, inches, or fractional parts of an inch, depending upon the size of the work and the degree of accuracy required. Working drawings also give ordinarily, the tolerances.

Principle of Orthographic Projection.—The representation of a plain rectangular block by means of separate views showing the shape as seen from the front, top, and side, will illustrate the principle of projection better than a drawing of some complicated mechanical device. At *A* (see illustration) this block, which is shaded, is represented as being enclosed by a

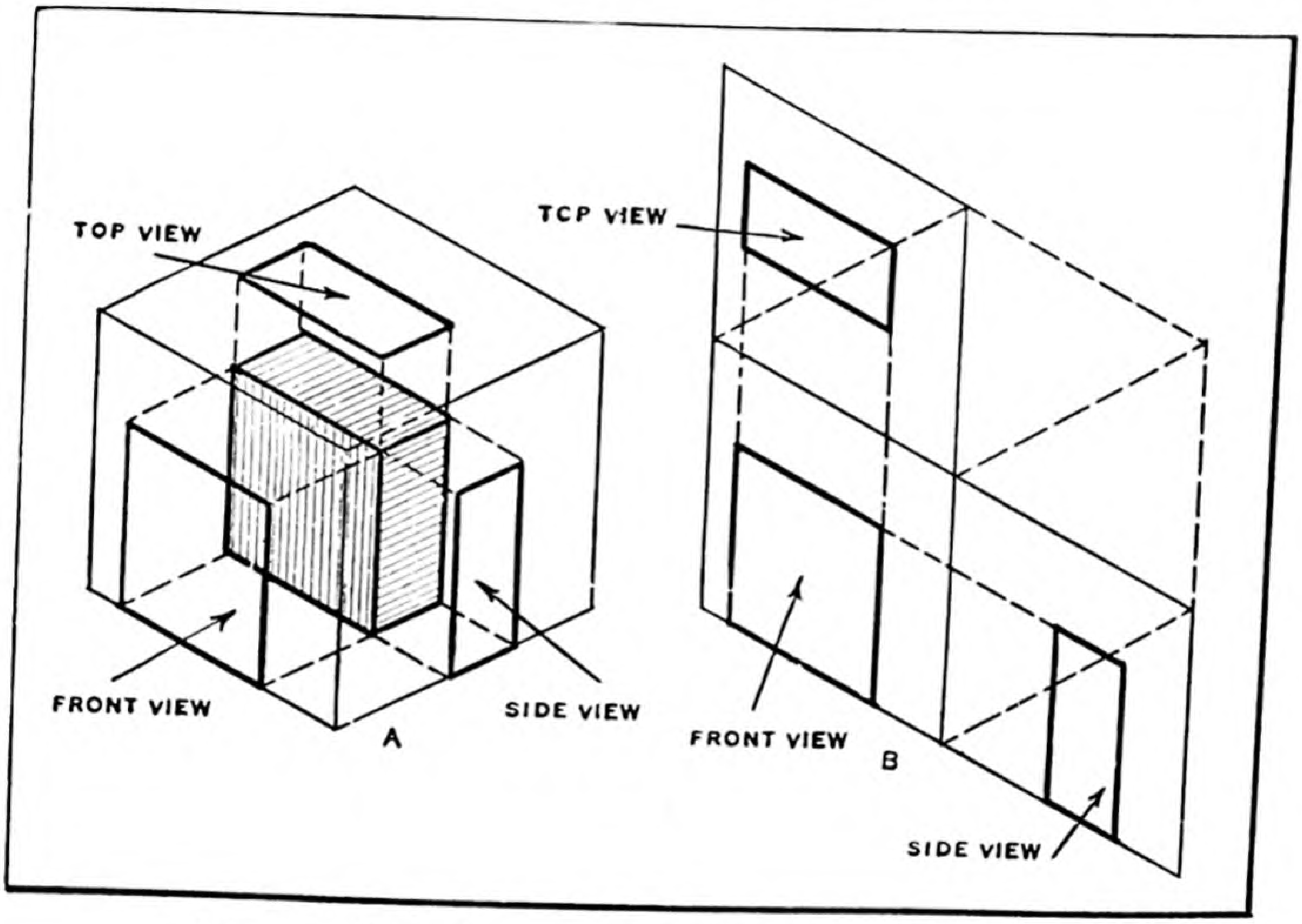


Diagram Illustrating Principle of Orthographic Projection

box formed of glass sides. If lines were extended or projected from the four corners of the block to the front of the box, as illustrated by the dotted lines, and these four points were joined as shown by the full lines, the square thus drawn would correspond to the front view. In the same way, if the corners of the side were projected to the side of the box and a rectangle drawn, this would correspond to the side view of the block. The top view is represented as being projected up to the top side of the box in a similar manner. These three views now represent a mechanical drawing made according to the orthographic projection method, but they lie in three different planes and on an actual drawing it is, of course, necessary to place all three views on a flat sheet or so that they all lie in one plane. If it is assumed that the top and right-hand side of the glass box are hinged

at the front edges, and that they are turned so as to lie in the same plane as the front side, the views will then appear as shown at *B*.

It will be understood that diagram *A* is intended merely to illustrate the principle of orthographic projection and that, in actually making a drawing of this block, the front view would ordinarily be drawn first to whatever size the block happened to be or to some reduced scale; then lines would be extended or projected for locating the end lines of the side and top views. The rectangles would then be completed by drawing lines representing the sides on both the top and side views, the distance between these lines corresponding to the thickness of the block.

Number and Arrangement of the Views. — A mechanical drawing may show only one side of an object or it may be composed of two or more views. Two or three views are the usual number, although four may be needed and sometimes it is necessary to add separate views or sections of important details. These detail views are frequently used to show some part which is not represented clearly enough in the general views. The views of mechanical drawings are arranged according to a definite plan. In the United States, the general practice is to place the top view above the front view, and the end view next to whatever end it represents. For example, if a view of the left-hand end is considered preferable to a view of the right-hand end, this end view is placed to the left of the front view, thus indicating, that it represents the left-hand end or side. If it were considered advisable to show both ends, then a right-hand view would be placed to the right of the front view. In some instances, a bottom view is needed, in which case it is placed below the front view.

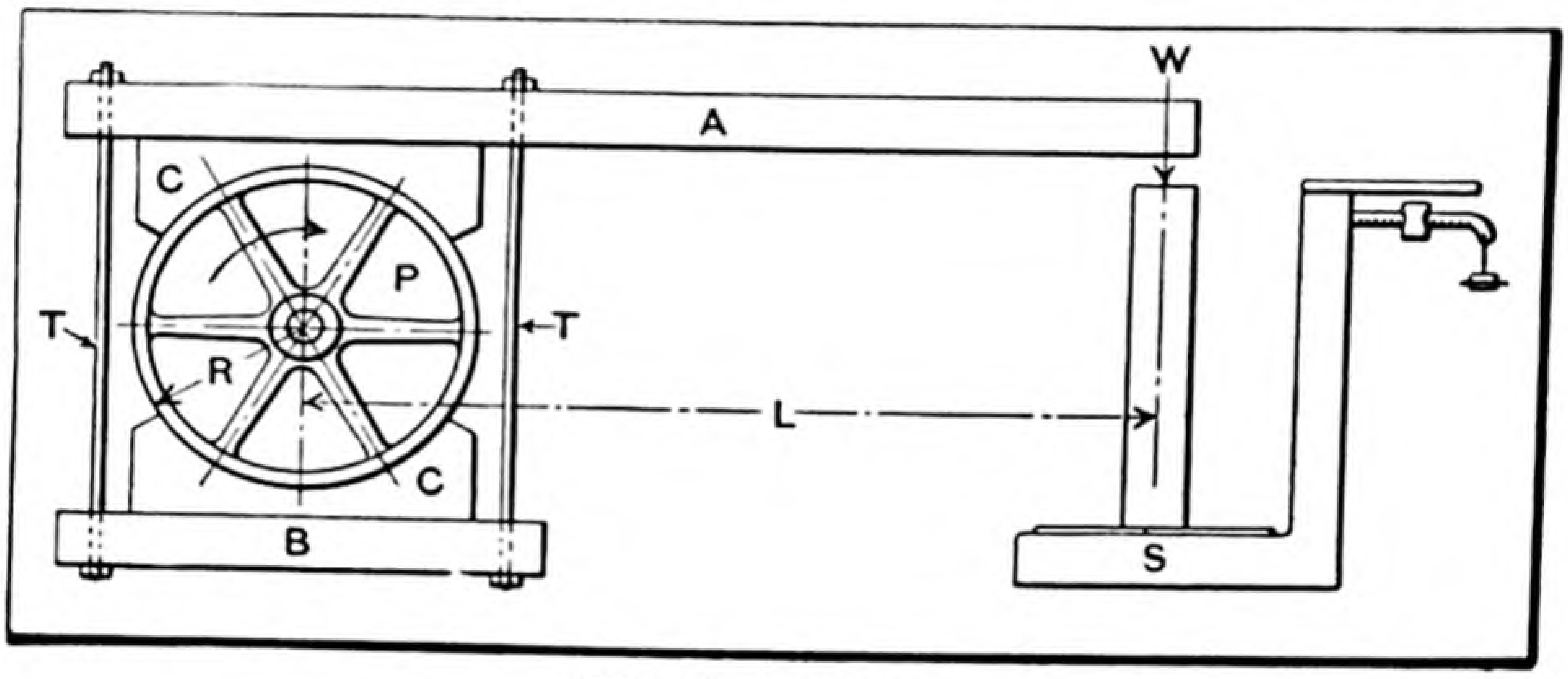
The view obtained by looking at the object from above is known as a *plan* view; that obtained by looking at the object from one of its sides and showing a vertical face is known as an *elevation*, and it may be either a *front elevation* or an *end elevation* (also known as *side elevation*), depending upon whether the view is of the front or side of the part drawn.

Third-angle and First-angle Projection. — When the views are placed with the plan above the front elevation, the right-hand end view to the right and the left-hand end view (when drawn) to the left, this is known as *third-angle projection*. In European countries, it is frequently the custom to use what is known as *first-angle projection*. With this method, the front elevation is placed at the top, the plan view, at the bottom, the right-hand end view at the left, and the left-hand end view at the right. The first-angle projection is also generally employed in architectural and structural work, as in drawings of bridges, etc. See Isometric Projection.

PRONY BRAKE. The simplest form of absorption dynamometer is the Prony brake (see diagram). This consists of a wooden beam *A* and a shorter beam *B*, connected by the two tie-rods *T*; fastened to the beams

are the two wooden pieces *C*. These pieces are sawed so that they fit the surface of the pulley *P*. By tightening the nuts on the tie-rods, the friction between the blocks and the pulley surface is increased. A knife-edge fastened to the beam *A* rests upon a support which transmits the pressure to the platform scale *S*. As the pulley revolves in the direction indicated by the arrow, its motion is opposed by the friction of the blocks. The brake absorbs the power generated or transmitted by the machine to which the pulley is attached.

The horizontal distance *L* between a vertical line through the axis of the pulley, and a vertical line through the knife-edge which supports the



The Prony Brake

brake, is known as the *arm* of the brake. The weight indicated by the scale when the brake is absorbing power is known as the *tare* of the brake. The weight which would be indicated by the scale, if the pulley were absolutely frictionless, is known as the *zero reading* of the brake. The difference between the tare and the zero reading is known as the *brake reading*. In order to determine the zero reading, the nuts are loosened so as to reduce the friction as much as possible, and the pulley is then revolved slowly forward and the scale reading taken. The pulley is then revolved slowly backward and the scale reading again taken. The average of these two readings is the zero reading. The power absorbed by the brake may be determined by the formula:

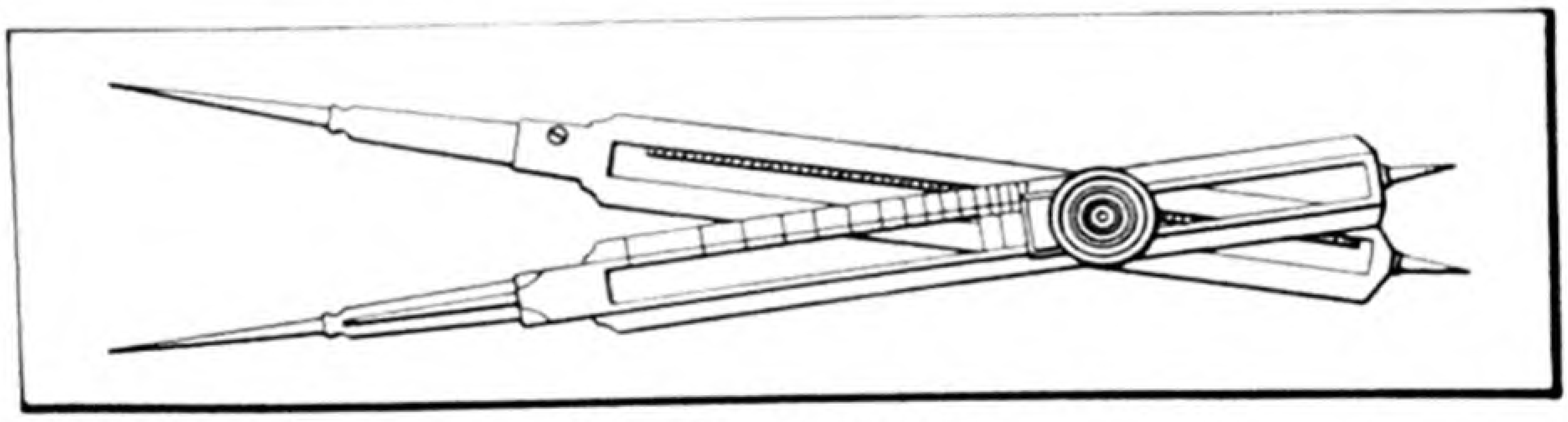
$$\text{H.P.} = \frac{2\pi LNW}{33{,}000}.$$

In this formula H.P. = horsepower absorbed by the brake; L = length of the brake arm in feet; N = number of revolutions of the pulley per minute; and W = brake reading in pounds.

PROPORTION. When two quantities bear such a relation to each other that as one is increased the other becomes greater, or, as one is decreased the other becomes less at the same rate, they are said to be in *direct propor-*

tion. The circumference of round bar stock is *directly proportional* to the diameter of the bar. If the diameter increases, the circumference will increase, and if the diameter is made less, the circumference will be less. If the relation between two quantities is such that as the one increases the other becomes smaller, and as the one decreases the other becomes greater in the same rate, they are in *inverse proportion.* When the relation between two quantities is such that the increase or decrease of one affects the other by a combination of two or more direct or inverse proportions, they are said to be in *compound proportion.* If one man can turn 50 bevel gear blanks in a day of 10 hours, then 5 men can turn 225 blanks in a day of 9 hours. The number of blanks turned by one man in 10 hours is in compound proportion to the number turned by 5 men in 9 hours, because the proportion is a combination of the proportion between the number at work and the proportion of the time they are working.

PROPORTIONAL DIVIDERS. Dividers of this type have slotted legs and a combined clamping screw and pivot which can be changed to any point desired. Thus, the double-pointed legs form practically two dividers,



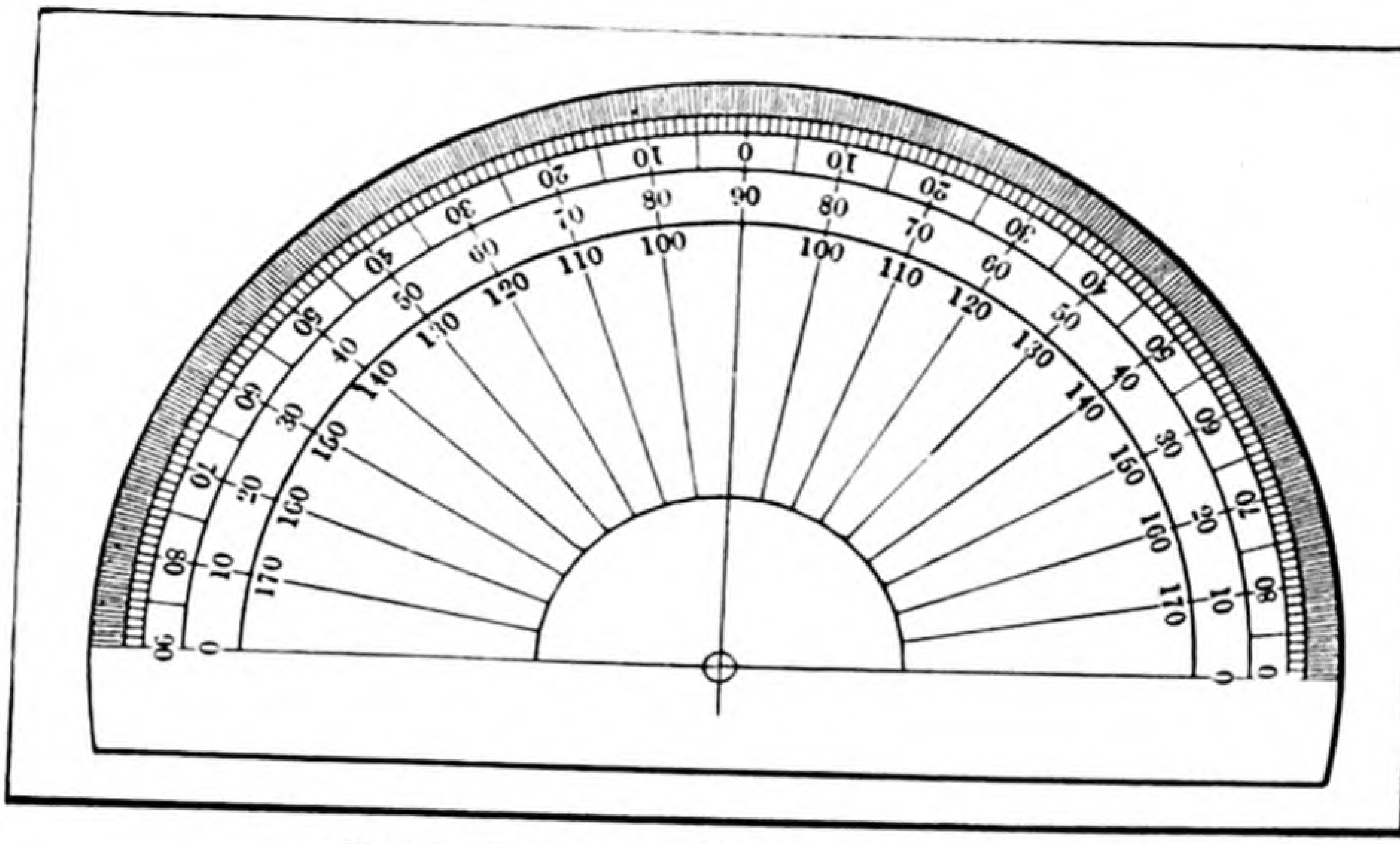
Proportional Dividers

the relative lengths of which are adjustable at will (see illustration). If the pivot screw is so placed that its distance from one point is one-third of the entire length of the legs from point to point, the dividers are set at a proportion of 1 to 2; that is, if the divider legs are opened until the shorter leg points are one inch apart, the points of the longer will be two inches apart. It follows that by shifting the position of the pivot screw any other relative proportion can be obtained. The position of the pivot screw is determined by graduations upon one of the legs, to which a single line upon the sliding pivot block may be adjusted.

PROPORTIONAL LIMIT. Proportional limit is the stress at which deformations cease to be proportional to the load. This value is determined with an extensometer.

PROTRACTOR. The protractor is used by draftsmen either for locating lines at a given angle or for measuring angles between lines. A simple form is shown by the illustration. Some protractors are provided with an

arm pivoted at the center and swinging around the circle. The smaller protractors are divided into degrees, while larger ones show half or quarter degrees. Those with a swinging arm are usually provided with a vernier scale by means of which small fractions of degrees, three or five minutes, for example, are read. The type generally used by machinists and toolmakers is known as the *bevel protractor*. It has a straight edge or blade which can be set at any angle with the base or stock; the angle for any position is shown by degree graduations.



Simple Protractor Used by Draftsmen

PROXIMATE ANALYSIS. In chemistry, a proximate analysis is a quantitative analysis in which the percentages of compounds (but not elements) that make up a substance are determined. For example, in a proximate analysis of coal, the percentages of volatile matter, fixed carbon, moisture, sulphur, and ash are determined.

P. R. R. CAR BRASS. This alloy is considered one of the best bearing bronzes. It is composed of 15 per cent of lead, 8 per cent of tin, 76.2 per cent of copper, and 0.8 per cent of phosphorus.

PRUSSIATE OF POTASH. Same as Cyanide of Potassium. See Cyanide.

PU. A Chinese length measure, legalized in 1908, equal to 1.6 meter, or 5 feet 3 inches.

PUDDLED STEEL. A slag-bearing steel made by the puddling process, which contains enough carbon to harden when suddenly cooled — a product rarely, if ever, made at the present time.

PUDDLING PROCESS. The puddling process is used in the manufacture of wrought iron. Pig iron is melted in a puddling furnace where

most of the silicon, carbon, phosphorus, and other impurities are separated from the iron. Pig iron melts at about 2100 degrees F., and wrought iron at about 2800 degrees F. The temperature during the puddling process is high enough to melt the pig iron, but not high enough to keep wrought iron in a liquid state. Hence, as soon as the small particles of wrought iron are freed from the excess of carbon, they form a spongy mass in which the small globules of iron are in a semi-plastic state. This mass is divided by the puddler into lumps of about 200 pounds each, which are formed into elongated blooms by a rotary squeezer, and, while hot, are rolled out into "muck bars." See Wrought Iron Manufacturing Methods.

PULLEY. The pulleys or wheels used for the transmission of power by belting are made either of cast iron, steel, wood, or a combination of these materials. Aside from the materials used in their construction, pulleys differ principally in regard to the form of the hub, the form of the rim, and the number and arrangement of the arms connecting the hub and the rim. *Cast-iron pulleys* may be either of the solid type, the clamp-hub type, or the slit type. The *solid pulley* is so named because the entire pulley is one solid casting. The *clamp-hub pulley* is a single casting and has a solid or continuous rim like a solid pulley, but differs from the latter in that the hub is split or divided, and it is provided with clamping bolts. When these bolts are tightened, the split hub grips the shaft tightly. Some pulleys of this class are held simply by friction, whereas others have, in addition to clamping bolts, a key or a key and set-screws. The *split pulley* is formed of two separate sections which are bolted together both at the hub and on opposite sides of the rim where the two parts are divided. This form of pulley can be placed between other pulleys on a shaft without removing either the pulleys or the shaft, by simply separating the pulley sections and clamping them together wherever the pulley is required. *Steel pulleys* which are made from steel plate, represent a comparatively modern development in pulley manufacture. The rim is either formed by rolling or by means of rolls and dies; the spokes are also made from sheet stock. These pulleys are of the split type and combine lightness with strength. The weight of one well-known make is about 45 per cent of the weight of a cast-iron pulley of corresponding diameter.

PULLEY CROWN. The face of a pulley is crowned by making the center larger in diameter than the edges. This is done for the purpose of guiding the belt in a straight line and thereby keeping it in position without using such mechanical means as belt guides or flanges for this purpose. The crowning, however, tends to keep the belt on only when the belt does not slip. A slipping belt will run off a crowned face pulley more easily than from a straight-faced one. Different authorities recommend very

different amounts of crowning. One authority recommends a crown or height at the center of $\frac{1}{20}$ of the width of the pulley for leather belting, and $\frac{1}{150}$ of the width for cotton belting. Another recommends from $\frac{1}{16}$ to $\frac{1}{8}$ inch of crown for each foot of width of pulley for high speeds, and $\frac{1}{4}$ inch of crown for low speeds. A formula which has proved satisfactory is as follows: $\frac{1}{200}$ of pulley face + 0.020 inch = height of crown.

PULLEY LATHE. The pulley lathe is a special design intended for turning and facing pulleys, gears, flywheels, couplings, and work of a similar nature. A well-known design of pulley lathe has two tool-rests, one located at the front and the other at the rear of the machine. The tool-rests are mounted on compound slides, one of which is utilized for diameter adjustment, and the other for feeding the tool when turning. These slides are carried by a table which swivels in the center and has a series of holes drilled on one side, through which a pin is inserted in order to locate the table at whatever angle may be required to give the desired taper or "crown" on the pulley. The tool-slides feed in opposite directions, so that each tool turns half of the pulley rim.

PULLEY SPEEDS. The following rule for the relation between the sizes of pulleys and the number of revolutions of two shafts can be formulated: The number of revolutions of one shaft multiplied by the diameter of the pulley on the same shaft, divided by the number of revolutions of the second shaft, gives the diameter of the pulley on the second shaft. To obtain the speed of the driven pulley in a compound drive, proceed as follows: Divide product of diameters of driving pulleys by product of diameters of driven pulleys, and multiply quotient by speed of first driving pulley.

PULSOMETER. The pulsometer, sometimes known as an aquometer, may be defined as a steam pump which acts partly by direct steam pressure and partly by vacuum. It has two working chambers into which the steam is alternately admitted. A partial vacuum is formed by the condensation of the steam, then water rushes into the chamber on account of the vacuum thus formed. When the chamber is full of water, the valve opens, steam enters again, and forces the water out into the delivery chamber, the steam condenses as before, causing the inflow of another supply of water, and the cycle is repeated. Two chambers are provided so that one is filled while the other is discharging. The pulsometer has neither rotating nor reciprocating parts. It will raise water to a height of about 26 feet, although it is not advisable to have a lift exceeding 20 feet, and it will force the water, if necessary, to a height of about 100 feet.

PUMP. A pump may be defined as a mechanical device or machine designed for elevating or conveying liquids against the action of gravity,

or for exhausting air or other gases from a closed vessel. A pump for liquids may be intended primarily for elevating the liquid from a source of supply below the pump up to the pump, or the principal purpose may be to force the liquid either to a much higher level or to some distant point by connecting the pump with suitable pipes. A mechanical device for withdrawing air from a closed vessel is ordinarily classified as a *pump*, but, if designed for compressing air or other gases, it is known as a *compressor* or *blower*.

Pumps are classified either with reference to some characteristic constructional feature or the particular class of service for which they were designed. The common types of pumps may be divided into several general classes, as follows: 1. *Reciprocating pumps* or those having a piston or plunger which is given a reciprocating movement in the pump cylinder. 2. *Centrifugal pumps* having a rotary impeller which, as a result of centrifugal force, causes the water to flow from the center to the periphery of the impeller with increasing velocity, and then out through the discharge outlet. 3. *Rotary pumps* which, according to the general usage of the term, differ from the centrifugal pumps in that the water or other fluid is forced through the pump by the direct application of pressure from rotating pistons or impellers and independently of centrifugal action. 4. Pumps in which the fluid is moved by the direct application of steam or compressed air and without employing a reciprocating piston or rotating impeller. In each of these four general classes, there are many different types.

Pumps of Crank-and-flywheel Type. — The crank-and-flywheel type of pump is practically a steam engine connected to a pump. This design is considered superior to the direct-acting type for many purposes, especially in regard to economy in the use of steam. The steam valve is operated either by some form of eccentric or crank, and the steam is cut off and used expansively. This type of pump, however, is more expensive than the direct-acting design of corresponding capacity, and, in some cases, it is difficult to decide which class is preferable. The crank-and-flywheel design gives a variable discharge, because the flywheel normally rotates at a uniform speed and the piston or plunger at a variable speed, which tends to cause shocks. The shocks resulting from a variable discharge may be reduced and the rate of flow made practically uniform by the use of several pump cylinders. A crank-operated pump, even in small sizes, is reliable in its action, which is not always true of single direct-acting pumps having steam-operated valves. One important objection to steam-driven crank-and-flywheel pumps is the difficulty of running them at slow speeds. The speed must be high enough so that the energy stored in the flywheel will carry the crank past its dead center. One method of overcoming this

difficulty is by using a by-pass, which allows part of the water to be returned to the suction side of the cylinder, thus decreasing the work done by the pump and its discharging capacity.

Power Pumps. — When pumps of the crank type are driven by a belt, by a motor, or by a prime mover which transmits motion through gearing but is not embodied in the design of the pump, the term "power pump" is commonly used in order to distinguish this class from those of the crank-and-flywheel design which are a steam engine and pump combined. Power pumps are often equipped with two or more cylinders, which is also true of the crank-and-flywheel type, having an engine forming an integral part of the construction. The duplex pump or two-cylinder design and the triplex pump having three cylinders are in common use, and a larger number of cylinders is sometimes employed. These pumps, whether of the single, duplex, or triplex pattern may be either single- or double-acting.

Pumps of Direct-acting Type. — One general class of reciprocating pumps is known as the *direct-acting* type, because there is no crankshaft or other revolving part, as the pressure in the steam cylinder is transmitted directly to the pump piston or plunger in a straight line by means of a piston-rod upon which the steam and pump cylinder pistons are mounted. This type of pump was invented by Henry R. Worthington, in 1840, who also developed afterwards the duplex type. If water is discharged each time the piston makes a stroke, the pump is known as the *double-acting* type. When water is drawn into and discharged from only one side of the piston, the pump is said to be *single-acting*. These terms should not be confused with the expression "direct-acting," which indicates a direct application of pressure from the steam cylinder through the medium of a straight piston-rod and without utilizing a rotating crank. The *duplex direct-acting* type of pump consists of two parallel pumps formed in one compact unit. The effect of this arrangement is that, soon after the piston or plunger of one pump passes the center of its stroke, the piston of the other begins its movement, so that there is practically a continuous pumping action. The duplex type of pump is superior to the single design in that it gives a more continuous flow of water. The single or simplex type, however, if carefully adjusted to give the maximum stroke, has less steam loss in the clearance spaces. The length of the stroke is also more definite owing to the action of the auxiliary valve, and is not affected by rod friction as in the case of a duplex pump. The duplex type, however, has a more simple valve-gear and is more reliable in operation. For pumping against comparatively high pressures or where a slow velocity of flow must be maintained, the duplex type is usually preferred.

PUMP AIR CHAMBER. See Air Chamber on Pump.

PUMP, AIR OR VACUUM. See Air or Vacuum Pump.

PUMP DISPLACEMENT. The displacement of a pump is equivalent to the "effective area" of the pump piston or plunger multiplied by the length of the stroke, or it is the volume included in a complete stroke. To determine the displacement in cubic inches per minute, multiply the effective area of the piston or plunger in square inches by the length of the stroke in inches and this product by the number of *discharging* strokes per minute. The effective area of a piston or plunger will be reduced somewhat on one side by the area of the piston-rod, except in the case of an outside end-packed plunger pump or a single-acting pump. Ordinarily the piston-rod area would not need to be considered.

PUMP DUTY. The duty of a pump represents the relation between the amount of work done by the pump and the amount of coal, steam, or number of heat units required for driving the pump. The duty may also be based upon the volume or weight of water pumped, in comparing the performance of a plant at different periods. If one pumping engine performs 130,000,000 foot-pounds of work during a given time, and the amount of coal or steam required is less than for another pumping engine operating under like conditions, obviously the former installation is more economical. The duty alone, however, is not the only factor to be considered. The duty of one pumping plant may be considerably higher than that of another, but there may also be a great difference in their relative initial costs. The more expensive plant might in some cases effect such a saving in coal consumption annually as to much more than offset the difference in initial cost, whereas, in other installations, a high duty might be purchased at too great a cost, especially if the service is severe and the high duty is obtained by an intricate or delicate mechanism that requires frequent repairs or renewal.

PUMPING, AIR-LIFT. See Air-lift Pumping.

PUMPING HOT WATER. When hot water or other hot liquids must be pumped, it is usually advisable, if not necessary, to place the pump low enough for the water to flow into it by gravity. While the boiling point of water is 212 degrees F. at atmospheric pressure, a reduction of pressure causes a reduction in the boiling temperature; consequently, when the temperature of the water exceeds about 180 degrees F., it cannot be lifted by the action of a pump, because the pressure of the vapor given off by the water in the suction pipe and pump cylinder counteracts the atmospheric pressure, which otherwise would force the water upward. If the temperature approaches this point, there should be a head of from 10 to 15 feet on the "suction" side, and the inlet pipe should preferably be larger than the regular size.

PUMP LIFT. See Lift of Water Pumps.

PUMP SUCTION. "Suction" is a term commonly applied to pumps to denote a decrease of atmospheric pressure within the inlet pipe and cylinder of a pump, as compared with the normal atmospheric pressure. During the suction stroke of a pump, which lifts water or some other liquid up to the pump cylinder from a lower level, the movement of the piston creates a partial vacuum within the cylinder on the inlet side, but as the normal atmospheric pressure is acting at the same time on the outer surface of the water with which the inlet or suction pipe connects, the water is forced upward because of the unequal pressure. What is commonly known as "suction," therefore, is, in reality, the forcing of water to a higher level by normal atmospheric pressure acting on a column of water connecting with a closed chamber or cylinder in which a partial vacuum has been formed. See Lift of Water Pumps.

PUMP SUCTION AND DISCHARGE PIPES. See Suction and Discharge Pipes.

PUMP VALVE LIFT AND AREA. In the design of pump valves, the combined area should be large enough to prevent excessive velocity and friction when the water or other liquid is passing through the valve seat; the suction valves should open easily and with little pressure, as otherwise, the atmospheric pressure would not overcome the resistance, especially if the vertical height from the source of supply to the pump cylinder were considerable; the lift of the valves should be small, to prevent excessive slip or leakage while the valves are closing; the valves should close rapidly, be tight when closed, durable, and easily replaced. Evidently there must be a compromise in the design of valves. For instance, stiff springs would close the valves quickly, but increase the pressure required for opening them; a high lift would be conducive to a free flowing movement of the water, but a low lift is desirable to prevent excessive losses through slip; large conical seats would provide straight passages for the water and reduce the frictional resistance to the flow, but would require large heavy valves and high lift. The general practice is to use a number of small valves and flat seats instead of the conical form, in order to reduce the amount of lift, although conical seats are sometimes used in connection with wing valves, etc. The lift of disk valves is usually about $\frac{1}{4}$ inch, regardless of the diameter. A wing valve having a 45-degree seat requires 40 per cent more lift than a flat valve to obtain a corresponding area of opening. The total valve area usually varies from 45 to 50 per cent of the plunger area, although it may be as low as 30 per cent and as high as 60 per cent, depending upon the speed at which the pump is to operate. The maximum velocity of the water while passing through the valves should be about 225 feet per minute.

By "valve area" is meant the area of the unobstructed opening or free passageway through the seats.

PUMP VALVE SPRING PRESSURES. For discharge valves, the spring pressure should equal approximately from 0.005 to 0.01 times the water pressure, with a maximum pressure of 5 pounds per square inch. For suction valves, when there is a suction lift, the pressure should equal from 0.25 to 0.5 pound per square inch.

PUNCH. A "punch," as the term is applied in pressed-metal work, is that part of a press tool which enters into an opening or cavity formed in the die section, as in drawing, forming, or blanking. The punch usually is the upper member, being attached to the press slide or ram, but it may be the lower member, as in the case of press tools of inverted design. Whenever the function of the upper and lower members is identical, as, for example, in embossing the sides of coins or medals, the upper die section would ordinarily be called the punch merely because the punch member of most dies occupies the upper position; nevertheless, it is form rather than location which, in general, is the distinguishing feature between the punch and its mating die.

PUNCH AND DIE CLEARANCE. The amount of clearance between a punch and die for blanking and perforating, or the difference between the size of the punch and the die opening, is governed largely by the thickness of the stock to be operated upon. For thin material, such as tin, for example, the punch should be a close sliding fit, as, otherwise, the blanks will have ragged edges, but for heavier stock there should be some clearance, the amount depending upon the thickness of the material. The clearance between the punch and die when working heavy material lessens the danger of breaking the punch and reduces the pressure required for the punching operation. In order to obtain the clearance between the punch and die, divide the thickness of the stock by a number or constant selected according to the following rules which apply to different materials: For soft steel and brass, divide the thickness of the stock by the constant 20; for medium rolled steel, divide by 16; for hard rolled steel, divide by 14. Whether this clearance is deducted from the diameter of the punch or added to the diameter of the die depends upon the nature of the work. If a blank of given size is required, the die is made to that size and the punch is made smaller. Inversely, when holes of a given size are required, the punch is made to correspond with the diameter wanted and the die is made larger.

PUNCHES, QUILL. See Quill Punches.

PUNCHING MACHINE SPACING TABLE. See Spacing Table.

PUNCHING PRESSURE. The following approximate rule may be used for rapidly finding the pressure in tons required for punching circular holes in sheet steel: Multiply the diameter of the hole, in inches, by the thickness of the sheet steel, and multiply this product by 90. The result is the pressure, in tons, required. To find the pressure required for punching holes in brass, multiply the diameter of the hole by the thickness, and multiply this product by 75. It will be understood that the foregoing rules give only a rough estimate of the punching pressure, since the latter depends upon the composition of the steel or other material to be punched, and may be varied by shear given to the cutting edges of the punch or die.

PUNCHING TOOLS AND MACHINES. The tools used for punching rivet and bolt holes in metal plates, angle irons, I-beams, channels, etc., vary in size and design from the small hand-operated types to the large power-driven machines found in boiler shops, ship yards, and similar places. The term "punch" is commonly applied to tools and machines of this class, although, strictly, the punch is that part of the tool or machine which, in conjunction with the die, actually performs the punching operation. Some punching machines are designed to punch holes exclusively, whereas other machines are adapted either to punching or shearing, by simply attaching suitable tools.

PUNCH PRESS RATING. See Power Press Tonnage.

PURPLE METAL. See Welsh Method.

PUSH-SPINDLE GRINDING ATTACHMENT. This is a grinding attachment for bench lathes in which the spindle, which is free to move in a lengthwise direction, is held by two bearings, and, when grinding, is transversed by hand, the spindle being driven by a round belt from an overhead countershaft. See Grinding Attachment, Push-spindle.

PUZZOLAN CEMENT. Same as Pozzuolanic Cement.

PYRITE. Pyrite is an iron ore containing 46.7 per cent of iron. In its chemical composition it is a sulphide, FeS_2, having a yellow color and producing a green or brownish-black streak on a porcelain plate. The specific gravity of pyrite varies from 4.8 to 5.2, and the hardness on the Mohs' scale, from 6 to 6.5. This ore contains too much sulphur to be used directly for the production of iron and is, therefore, first desulphurized, sulphuric acid being extracted from the ore as an important product. The ore often contains copper, and, after the sulphuric acid has been extracted, the copper is obtained by means of the so-called "wet process," after which the ore is used as an iron ore. There are large deposits of this ore and it is likely that, when the richer deposits of oxidized ores have been exhausted, it will gain considerable importance in the iron industry.

PYRO-METALLURGICAL PROCESS. This is a method for obtaining a metal from its ores by means of smelting. See Dry Process.

PYROMETER PASTE. Salt mixtures made in the form of paste are sometimes used for determining temperatures. Different pastes of various melting points can be placed along a steel bar and inserted in the furnace, retort, flue, or other point where it is required to make a temperature determination, and, by noting which paste melts and which does not, the temperature may be determined.

PYROMETERS. A pyrometer is any device used for measuring temperatures from about 500 degrees F. and higher. There are a number of pyrometers based on widely different principles and of entirely different construction. The most commonly used pyrometers are of the *thermo-electric* type. In this type, temperature variations are determined by the measurement of an electric current generated by the action of heat on the junction of two dissimilar metals. The thermo-couple, consisting of two pieces of dissimilar metals, is placed at some point within the furnace and is connected by wires with a meter or indicator which may be close to the furnace or in some other part of the plant. That end of the thermo-couple which extends into the heated chamber is known as the "hot end," and the two pieces of dissimilar metals do not touch except at this hot end. The opposite or "cold ends" which are free or separated are connected by wires with whatever indicating or recording apparatus is installed. When the hot end is heated, a feeble electric current is generated. The electromotive force thus developed depends upon the kind of metal of which the thermo-couple is made, and upon the difference between the temperatures of the hot and cold ends. The current is conducted by wires leading to the meter or indicating part of the pyrometer outfit. The instrument may be calibrated or graduated to give readings directly in degrees.

The method of utilizing the current to indicate degrees of temperature varies with pyrometers of different makes. Many pyrometers are so designed that the indicating hand or pointer is displaced, by the direct action of the current upon a moving element, an amount depending upon the strength of the current generated. In this case, the indicating instrument is a form of galvanometer or millivoltmeter. As a feeble current is generated, a sensitive instrument is required, and one of the important features is the method of arranging and supporting the moving element so that it is actuated by slight changes in the strength of the current.

The variation in electric conductivity due to changes in temperature is the principle upon which the *resistance pyrometer* is based. This type is very accurate for temperatures below 1600 degrees F., but should not be used continuously for higher temperatures. The maximum temperature is about 2200 degrees F.

Radiation pyrometers measure radiated heat and are adapted for very high temperatures. The Féry radiation pyrometer is practically a reflecting telescope having a concave mirror which focuses the radiant heat of the object upon the "hot" junction of a small thermo-couple. There is a diaphragm for reducing the aperture when the instrument is pointed at a very hot object, in order to prevent overheating the thermo-couple. With the Brown radiation pyrometer, the rays of heat from the furnace or molten metal which enter the pyrometer tube are reflected from a concave mirror onto a sensitive thermo-couple, and the temperature is indicated on a millivoltmeter, graduated in temperature degrees, the same as a thermoelectric pyrometer. No part of the instrument is inserted in the high heat to be measured. If the temperature of a furnace is to be measured, the tube is either held on a tripod or in the hand, and is pointed toward the door of the furnace. The temperature can then be read off on the indicator.

There are several classes of *optical pyrometers*. One type indicates the temperature by heating the filament of an electric lamp to the same color as that of the incandescent body, the temperature of which is required. The small low-voltage lamp is placed inside a tube through which the heated object is observed. To determine the temperature, the current for the lamp is so regulated (by means of a rheostat) that the color of the lamp filament corresponds to that of the heated object which is observed through the instrument. The current then being consumed is indicated by a milliammeter, and the corresponding temperature is determined. There are several other types of optical pyrometers. These pyrometers may be used to estimate the highest temperatures, and may be used for temperatures above 3000 degrees F., both in laboratory and industrial work. See also Potentiometer.

PYROMETERS, AUTOMATIC CONTROL TYPE. The pyrometer that automatically controls furnace temperatures is so arranged that the moving element of the instrument not only indicates the temperature by its position relative to a scale, but by combined mechanical and electrical apparatus, controls the temperature, within certain limits, by regulating the heat supply. The pyrometer can be set for any temperature desired within certain maximum and minimum limits. If the furnace is electrically heated, the temperature may be regulated by solenoid-operated switches, which either open and close the main circuit, or are used in conjunction with rheostats. In the case of gas or oil-fired furnaces, electrically or pneumatically operated controlling valves or dampers are employed, the opening and closing of these valves being governed by the pyrometer.

PYROMETERS, HIGH- AND LOW-RESISTANCE. A pyrometer may be of either a high- or a low-resistance type, depending upon the amount

of internal resistance. For instance, this internal resistance may be only 5 ohms in a low-resistance pyrometer and 500 ohms or more in a high-resistance instrument. In a high-resistance pyrometer, less of the current generated by the thermo-couple is utilized by operating the moving or indicating element. The object of introducing high resistance is to avoid errors due to changes of resistance in circuit, such as would result from atmospheric changes of temperature or from changes in the length of the lead wires or of the thermo-couple itself. When the internal resistance of the pyrometer is, say 600 ohms, changes in the resistance of the circuit such as would result from changing the length of the leads from a few feet to several hundred feet, may be entirely negligible because the change of resistance represents such a small percentage of the total resistance. There is a practical limit, however, to the amount that the resistance should be increased, as the greater the resistance the more difficult it is to construct a movable element which will readily respond to changes in the strength of the current resulting from variations in the temperature of the thermo-couple. While low-resistance instruments are comparatively cheap, they are not so accurate as the high-resistance pyrometers, and should be used only when the leads connecting with the thermo-couple are short, on account of the greater resistance changes in long leads. The contact resistance at the binding posts, where the leads are joined to the couple and to the instrument, may also affect the readings, and these contacts should be very good for a low-resistance instrument. Most of the pyrometers of the millivolt-meter type used in connection with the heat-treatment of steel are high-resistance instruments. The high-resistance type is not only desirable when the leads are long, but it is especially adapted for installations where one pyrometer is connected (by a multiple switch) to several different thermo-couples located at various distances from the indicating instrument.

PYROMETERS, INDICATING. Many of the pyrometers used in heat-treating plants may be designated as the "indicating" type, since the temperature variations are shown by the position of a hand or pointer relative to a graduated scale. The indicating instrument may be located close to the furnace or in some central station or controlling room. When it is by the furnace, the furnace operator controls the temperature either according to his experience with similar work, or possibly by reference to data previously recorded. This is a common method in small plants, but where a large heat-treating department is installed, a centralized system of control is quite general.

PYROMETERS, RECORDING. A recording pyrometer is provided with some kind of marking device which traces either a continuous or a dotted line upon a chart graduated with reference to temperature and time. By

referring to one of these charts, the temperature at any period within the range of the chart is shown graphically. The chart may be graduated in minutes of time and may cover a total range of, say, two hours, or the main divisions may represent hours and cover either a twelve-hour period or a twenty-four-hour day. Pyrometers are also made to give a continuous record over long periods. These charts differ in form, some being circular disks and others of rectangular shape. The charts or records of temperature variations obtained by means of recording pyrometers are not only valuable for future reference, but also enable the superintendent, foreman, or attendant to watch readily the operation of any furnace by inspecting the chart whenever convenient. Besides showing the temperatures, the charts indicate the general trend of any changes which may occur. The use of recording instruments tends toward greater uniformity in the quality of heat-treated products.

Multiple Recorder. — Where a heat-treating plant contains two or more furnaces, a pyrometer may be installed that will record automatically on a chart temperature variations in each furnace to which it is connected. This type of pyrometer is generally used when the heat-treating process requires a half hour or more for its completion. The pyrometer may be designed especially for multiple recording or have an auxiliary connecting or switching device. One type of multiple recorder will produce from two to eight records on one chart, and when four, six, or eight records are needed, these are printed on the chart in different colors to avoid confusion

PYROMETERS, SIGNALING. In order to dispense with the services of a man who controls temperature signals from a central station, automatic signaling pyrometers have been developed. One type of signaling pyrometer is so arranged that the pointer is depressed at intervals of ten seconds upon contacts corresponding to the red, white, and green lights. The particular contact upon which the pointer is depressed depends, of course, upon the position of the pointer which, in turn, varies according to the temperature. The three contacts may be adjusted to a position corresponding to the temperature to be maintained. The periodic movements of the pointer for depressing it upon the contacts are derived from a small motor. This motor, through a crank mechanism, lifts the pointer, which descends by gravity upon whichever contact it is over at the time, and one of the three lights is switched on through a three-point relay switch. The current for lighting the signal lamps is made and broken by an auxiliary device and does not flow through the instrument. This automatic signaling pyrometer eliminates the man who, in connection with ordinary installations, is required to read the temperatures at the central pyrometer, and signal to the furnace attendants. This instrument, when provided with a suitable

switching mechanism, may be arranged to operate batteries of lights for different furnaces.

PYROMETERS, THERMO-COUPLES. When two dissimilar metals are held in contact and the point of contact is heated, a small current of electricity is generated, and in most cases the magnitude of this current is proportionate to the intensity of the temperature. The requirements of a good thermo-couple are: 1. A high melting point of the elements. 2. The property of generating as large an electromotive force as possible, and an electromotive force which will increase as nearly as possible in direct proportion to rise in temperature, in order to obtain a uniform scale. 3. Constancy of couples throughout their life. There are two general classes of metals used for the thermo-couples, known as base metals and rare metals, the former being the more widely used. The latter are much more expensive, but they are adapted to higher temperatures. Base metal couples are ordinarily used in conjunction with the heat-treatment of carbon steels, but rare metal couples are often used in preference in the case of high-speed steels. Base metal couples are usually made either of some nickel alloy or of iron-constantan, and rare metal couples of platinum in conjunction with a platinum alloy. The base metal couples have several advantages, especially as applied to pyrometers for use in heat-treating plants. In the first place, the base metal couple generates an electromotive force which is several times as great as that derived from a platinum alloy couple; consequently, the indicating instrument can be made less delicate and is not so likely to become deranged. Another advantage is that for a unit increase in the temperature of a base metal couple there is approximately a uniform increase in electromotive force, the relation between the two being represented by a line that is nearly straight. The result is that the pyrometer has graduations or divisions that are practically equal or even, which is preferable to a scale having short divisions for the lower temperatures and longer ones for the higher temperatures, or *vice versa*. Still another advantage is that the increase of resistance due to an increase of temperature is very low as compared with a rare metal couple. It is essential that all thermo-couples which may be used at different times in conjunction with a pyrometer generate the same electromotive force for a given temperature; in other words, the thermo-couples should be interchangeable. Without this uniform relationship between the temperature and the electromotive force generated, the pyrometer readings will not be correct. In addition to this quality of uniformity or accuracy, a reasonable degree of durability is also important.

QUADRATIC EQUATION. A quadratic equation is one in which the unknown quantity is contained in the second power or in the first and second powers. A quadratic equation is sometimes called an equation of the "second degree." See Equations.

QUADRIC INCH. The expressions "quadric inch" and "quadric foot" are sometimes used in connection with values denoting the moment of inertia. The moment of inertia is expressed by the fourth power of a length dimension; hence, the expression "quadric inch, foot," etc., according to whether the inch or foot is used as the unit length. In expressions containing the moment of inertia, the quadric dimension is frequently abbreviated $in.^4$, $ft.^4$, etc. The expression is not very commonly used.

QUADRIVALENT. Quadrivalent, also known as *tetravalent,* is a term used to indicate that one atom of an element will combine with four atoms of another element.

"QUALIFYING" AUGER BITS. Auger bits are first formed by trip hammers and then by drop hammers in conjunction with nicely formed dies. After the flash is cut off, the forgings are made cylindrical and to the correct size. This operation is termed "qualifying." In some plants qualifying is a cylindrical grinding operation performed on a cylindrical grinding machine. In a few instances sandstones are still used for this operation, but where this is the case, the machines are of the semi-precision type. Another method which is very common is to use a steel wheel revolving at a very high speed, the auger bits being revolved on centers as in a cylindrical grinding machine. The action is then one of surface flowing of a ductile metal, caused by heat produced. In the latter method a burr is thrown into the hollows of the auger, and it is for this reason that this operation is done immediately after forging, so that later grinding operations will remove this burr.

QUALITATIVE ANALYSIS. In chemistry, qualitative analysis is the resolution or division of complex chemical substances into their elements, when only the kind of constituent elements are determined, but the percentage contained of each is not of importance. See Chemical Analysis.

QUANTITATIVE ANALYSIS. In chemistry, quantitative analysis is the resolution or division of complex chemical substances into their elements when both the constituent elements and the percentages of each that are contained in the original substance are determined. See Chemical Analysis.

QUARTER HAMMER. This is a small sledge hammer weighing less than eight pounds. See Sledge Hammers.

QUARTERING MACHINE. A quartering machine is a special design of horizontal boring machine that is employed exclusively for boring the crankpin holes in pairs of locomotive driving wheels. The holes in each pair of wheels must be 90 degrees apart and they are bored after the wheels are forced on the axle. The pair of wheels is placed between the centers of the quartering machine, and the holes are bored by two short boring-bars. One bar is located on each footstock or center base, and it is carried by a slide that is adjustable. The angle between the ways upon which the slides are mounted is 90 degrees, so that the angular distance between the crankpin holes is also 90 degrees, irrespective of the adjustment of the boring-bars which is made to conform to the radius of the crankpin circle. The crankpins in each pair of driving wheels are placed 90 degrees apart in order that one side will be developing maximum power when the other side of the locomotive is passing the dead center position, thus equalizing the distribution of the power developed and making it impossible for both sides of the locomotive to be on the dead center at the same time.

QUARTERNARY ALLOY. A quarternary alloy is an alloy consisting of four elements. When applied to steel, such an alloy contains, in addition to iron, three alloying elements. Carbon is one of these, and the other two may be chromium and nickel, silicon and manganese, etc.

QUARTER-PHASE CIRCUIT. The expression "quarter-phase" circuit, also known as "two-phase" circuit, is used to characterize a combination of two circuits, energized by alternating electromotive forces which differ in phase by a quarter of a cycle — that is, by 90 electrical degrees.

QUARTER-TURN BELT DRIVES. When two pulleys are mounted on shafts located at right angles to each other and are connected by a belt, this is known as a *quarter-turn drive*. Such drives should be avoided, if possible, because the belt is distorted as it twists around from one pulley to another, and, moreover, the contact between the belt and the pulleys is reduced, owing to the angular position of the belt. When installing a quarter-turn drive, it is important to allign the pulleys in the proper manner. A general rule for aligning pulleys connecting shafts which are not parallel is as follows: The center of the face of the *driven* pulley must be aligned with the center of that face of the *driving* pulley from which the belt leaves.

QUARTER-TURN GUIDE. A quarter-turn guide, in rolling mill practice, is a mechanical means for turning a bar, that has passed through one pass in a rolling mill, through an angle of 90 degrees before it passes through the next pass in a continuous mill.

QUEEN'S METAL. Queen's metal is a tin-antimony-copper bearing alloy containing, in addition to the metals mentioned, a small percentage of

either zinc or bismuth. One composition of the metal contains 88.5 per cent of tin, 7 per cent of antimony, 3.5 per cent of copper, and 1 per cent of zinc. Another composition contains 88.5 per cent of tin, 7 per cent of antimony, 3.5 per cent of copper, and 1 per cent of bismuth. Owing to the high percentage of tin, the metal is rather expensive, but, at the same time, the high tin content makes it a high-grade bearing metal.

QUENCHING BATHS. Quenching consists in plunging heated steel into a bath thus cooling it quickly. By this operation the structural change caused by the heating seems to be "trapped" and permanently set. Were it possible to make this cooling instantaneous and uniform throughout the piece, it would be perfectly and symmetrically hardened. Clear cold water is commonly employed for ordinary carbon steel, and brine is sometimes substituted to increase the degree of hardness. Sperm and lard oil baths are used for hardening springs, and raw linseed oil is excellent for cutters and other small tools. The effect of a bath upon steel depends upon its composition, temperature, and volume. The bath should be amply large to dissipate the heat rapidly, and the temperature should be kept about constant, so that successive pieces will be cooled at the same rate. Greater hardness is obtained from quenching in salt brine and less in oil, than is obtained by the use of water. This is due to the difference in the heat-dissipating qualities of these substances. High-speed steel is cooled for hardening either by means of an air blast or an oil bath. As a general rule, water should not be used for high-speed steel. Various oils, such as cottonseed, linseed, lard, whale oil, kerosene, etc., are also employed; many prefer cottonseed oil. Linseed has the objection of becoming gummy, and lard oil has a tendency to become rancid. Whale oil or fish oil give satisfactory results, but have offensive odors, although this can be overcome by the addition of about three per cent of heavy "tempering" oil.

QUENCHING BATHS, ALKALINE. Alkaline solutions cool steel through the critical range or from the hardening temperature to the black stage at a slower rate than oil, which governs the hardness of the steel. In consequence, the use of alkaline solutions gives the least amount of hardness possible to the work when quenching in a liquid to the cold stage. The loss in hardness is compensated for by the toughness obtained and the elimination of the tendency to warp. When the hot steel is plunged into the bath, the "shock" or rapidity of cooling is lessened and the hardness of the case of the steel is thereby reduced; hence the strains, etc., in the main bulk cannot bend it to a position of strain equilibrium. Alkaline baths are adaptable to treating steel parts such as axles, etc., when certain physical properties are desired. In case-hardening, alkaline solutions are well adapted for core refinement of delicate parts that would warp excessively if quenched in a

faster cooling medium. Materials employed in preparing alkaline quenching solutions are lye, soda ash, soap, etc., and these are used in various amounts according to the final results desired. Alkaline solutions are not generally used, for the reason that, with the different grades of steels that can be obtained, a grade can almost always be selected that will give the desired physical properties by quenching in oil or water.

QUENCHING BATHS, OIL. Oil is used extensively as a quenching medium, since it gives the best proportions of hardness, toughness, and warpage for standard steels. Fish and cottonseed oils have been supplanted to a great extent by special compounded oils of the soluble type. The soluble properties enable the oil to make an emulsion with water, which constitutes a slight advantage, because if water gets into the oil it combines with it to form a medium which cools the work slightly faster than oil alone. In non-soluble oils, the water does not emulsify with the oil, but goes to the bottom of the quenching tank, and as the hot steel passes through the oil to the water it receives unequal hardening strains. A good quenching oil should possess a flash and fire point sufficiently high to be safe under the conditions used, and 350 degrees F. should be about the minimum point. Its viscosity should be such as to allow it to drain readily from the work and circulate itself freely by a thermo-syphon action. The specific heat of the oil regulates the hardness and toughness of the quenched steel, and the greater the specific heat is, the harder the steel will be. Viscosity must also be considered in this respect to some extent. Specific heats of quenching oils vary from 0.20 to 0.75, the specific heats of fish, animal, and vegetable oils usually being from 0.2 to 0.4, and of soluble and mineral oils, from 0.5 to 0.7. The oil should not contain water, should not gum in use, should not be of a disagreeable odor, or become rancid, or have a skin-drying effect on the bodies of the workmen. A great many concerns use paraffin and mineral oils for quenching, while a few use crude fuel oils.

Oil Bath Cooling Methods. — Keeping the quenching bath cool is important when using oil, and there are three ways of doing this: (1) By using a large quantity of oil. (2) By circulating the oil past colder objects. (3) By passing colder liquids in pipes through the oil. When using large quantities of oil, the oil will retain approximately its surrounding temperature if there is one gallon used for every pound of steel quenched per hour, and the circulation of the oil past the steel is about one gallon per hour. The oil circulation may be accomplished by the agitation of the oil caused by quenching the work and by the thermo-syphon action of the oil, or by storing the oil in a separate tank and pumping to and from the quenching tank.

When circulating the oil past colder objects, the oil is pumped from the quenching tank through a pipe to the cooler. The cooler may be a brine

tank cooled by an ammonia refrigerating system; a reversed water heater in which the oil passes through many lengths of piping about which cold water flows; a series of metal sheets set at angles on which the oil is sprayed and allowed to flow from one to the other in a downward zig-zag motion after which it is collected and pumped back to the quenching tank; or an open tank in which half of the periphery of many revolving disks are placed in the oil, and air is blown over the exposed disks which are covered with a film of oil as they revolve. When passing colder liquids in pipes through the oil, the oil itself is not circulated. Pipes may be laid in the bottom or at the sides of the tank through which cold water can be forced. Cold brine from an ammonia refrigerating system is used in large installations of this type.

QUICK-BREAK LEVER SWITCHES. A quick-break lever switch is a plain lever switch with each pole equipped with an auxiliary blade pivoted to the main blade and so arranged that the auxiliary blade will remain in contact in the contact clip until the main blade has been opened to a certain predetermined amount. Then the auxiliary blade is forced out of contact by an arrangement on the main blade, and quickly follows the main blade due to the action of a spring. The current in the circuit when the switch is opened under load is broken on the auxiliary contacts which are moving rapidly when they leave the contact, thus quickly rupturing the arc without damage to the main blade.

QUICK CHANGE-GEAR MECHANISMS. On many modern lathes, the changes of feed for turning and screw cutting are obtained by means of a system of gearing which enables the changes to be made rapidly, by simply shifting one or more levers. A table or index plate attached to the machine, shows what pitches will be obtained for different positions of the levers.

QUICKSILVER. See Mercury.

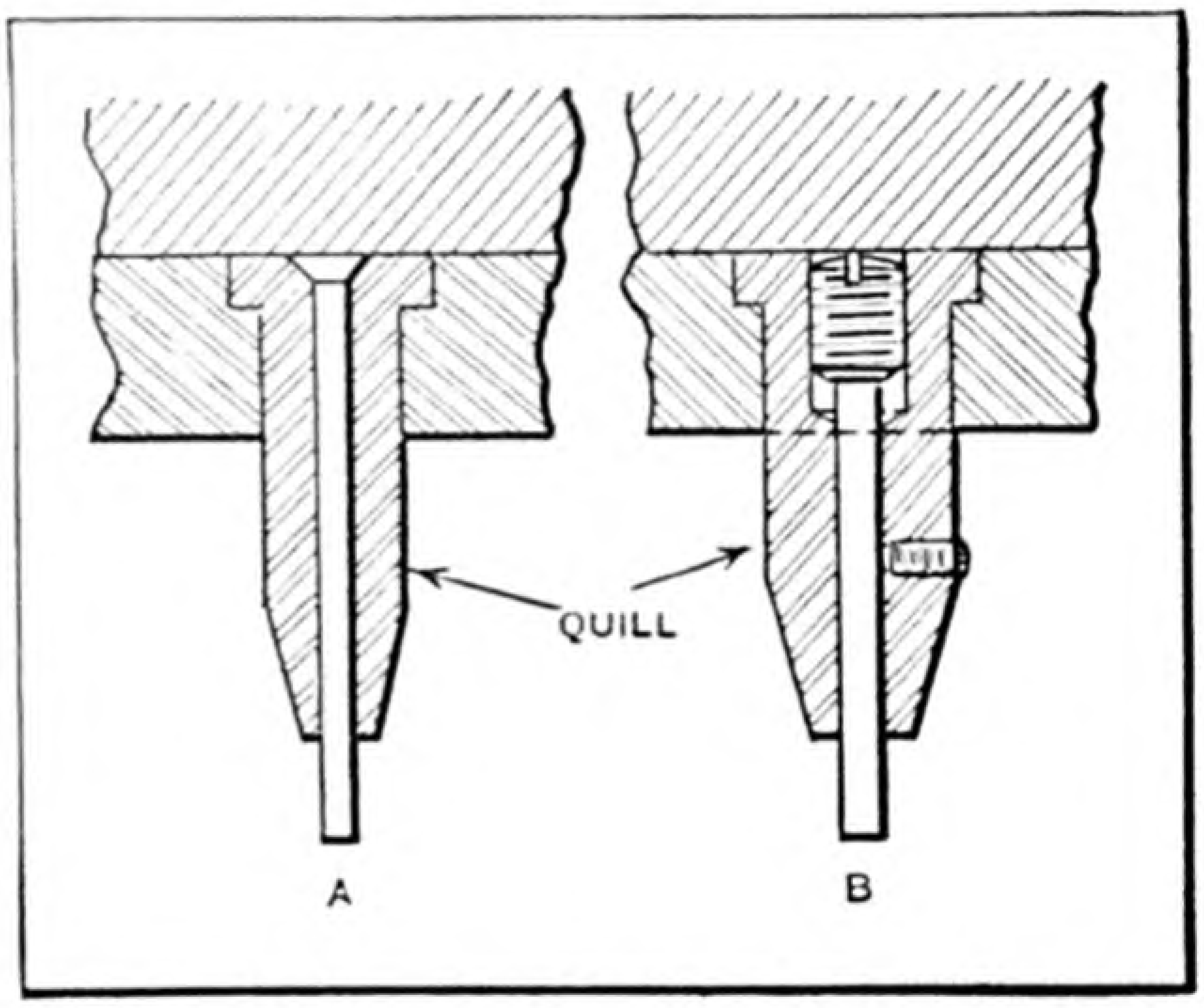
QUILL FOR BENCH LATHES. A quill is an auxiliary spindle that is used on bench lathes for holding and revolving parts that require extreme accuracy in the location of holes, etc. The spindle revolves in a bearing or "quill rest," which, in turn, is mounted on the bench-lathe bed in front of the headstock. The work may be held either in a "chuck quill" or be attached to a "faceplate quill;" special fixtures are also attached to the end of the quill spindle.

The *quill driver* is a special coupling used for driving a bench-lathe quill so that any jar that may be imparted to the lathe spindle by the belt joint as it passes over the cone pulley is not transmitted to the quill spindle.

QUILL PUNCHES. Piercing punches of the type shown at *A* and *B* are called "quill" punches and are used where a large amount of stock is

to be pierced or when the stock is thick in proportion to the diameter of the punch. The piercing punch is held in position by the quill or punch-holder which is driven tightly into the punch-plate. The piercing punch is slightly driven into the holder and is made of drill rod, so that it can very readily be replaced in case it is broken. The upper end of punch *A* is riveted over as shown. The holder shown at *B* is equipped with a backing screw for the punch so that the latter can be adjusted vertically. The punch is retained by a set-screw.

Another method of guiding and steadying a slender punch, which is sometimes employed, consists in using straight drill rod for the punch which is supported at its lower end by the stripper plate attached to the die. Instead of making the punch straight throughout its length, it is good practice to use drill rod of standard size and then turn down the lower end for a length of about $\frac{1}{4}$ inch and to the diameter of the hole to be pierced. This allows the body part of the punch to be well entered into the stripper plate, in which it should be a close fit, before the piercing operation begins, so that the punch is rigidly supported when at work. The body of the punch should be a driving fit into the punch-plate and be riveted over at the upper end and filed flush. When made in this way, the punch will be rigid, even though it is used for piercing small holes, and, if it is well supported in the stripper plate, a much smaller punch can be employed than would be possible otherwise. When piercing heavy stock, it is well to insert a hardened steel disk in the punch-holder just above each piercing punch. This disk prevents the end of the punch from compressing the metal and thus working a depression into it, which would allow the punch to slide up and down at each stroke of the press.



Quill Punches

QUINQUIVALENT. Quinquivalent, also known as *pentavalent*, is a term used to indicate that an atom of one element will combine with five atoms of another element.

RABBETED JOINT. The rabbeted joint for the corners of patterns, boxes, etc., differs from a plain butted joint in that one corner piece is rabbeted to form a shoulder for supporting the other corner piece against inward thrusts. See Joints Used in Patternmaking.

RACE. The race of a ball bearing is the groove in which the balls roll; the term is also applied to the part in which this groove is cut. The "inner race" is the part mounted on the shaft, and the "outer race" is the part surrounding the balls and mounted in the supporting structure.

RACK. A rack may be defined as a spur gear having a radius of infinite length, the pitch-line of a rack being straight. Racks are commonly used to transmit from a rotating pinion, linear motion to a machine table, slide or other part. In the involute system of gear teeth, the sides of an unmodified rack tooth are straight and inclined from the vertical to the same angle as the pressure angle. The basic rack of the standard $14\frac{1}{2}$-degree composite system (full depth tooth) has a straight mid-section and cycloidal curves above and below.

RACK, BASIC FOR STANDARD GEAR TEETH. See Gear Tooth Standard, American.

RACK CUTTING. Rack teeth are cut ordinarily by milling with a formed cutter, although in some shops they are cut by planing with a formed tool. While the teeth of racks may be cut by a generating method, this has been applied to a limited extent only. The milling process is employed much more than any other for commercial rack-cutting. The rack teeth are produced either by feeding a formed cutter across the rack blank or by causing the rack to feed past the cutter. After milling each tooth space, either the rack or the cutter is indexed an amount equal to the linear pitch of the rack teeth (or circular pitch of the mating pinion) except when two or more finishing cutters are used.

Rack-cutting Attachment. — This attachment for a milling machine has a horizontal cutter spindle which normally is at right angles to the machine spindle. This cutter spindle is so mounted in the body of the attachment that the cutter may be traversed across the work without interference between the work and the attachment. The spindle is driven from the main spindle of the machine through suitable gearing, and the rack teeth are formed by cutting spaces straight across the blank; after each tooth space is milled, the machine table and work is indexed for cutting the next tooth space.

RADIAL BEARING. A radial bearing, also known as a journal bearing, is a support for a shaft or axle, in which the load acts at right angles to the

axis of the shaft. This term is used in contradistinction to thrust bearing, in which the load acts parallel to the axis of the shaft. A *radial ball bearing* is a ball bearing in which the bearing with its balls surrounds a shaft, and the load, acting at right angles to the shaft, is transmitted through the balls.

RADIAL DRILLING MACHINE. A radial drilling machine differs from the regular upright machine in that the drilling head is mounted upon a radial arm adjustable vertically and also horizontally by swinging the arm about its supporting column. The drilling head may also be moved along this radial arm, to the required position for drilling, instead of adjusting the work or table each time a new hole is to be drilled. Because of this feature, the radial drilling machine is especially adapted to heavy work, as a number of holes can be drilled by simply adjusting the drill head to the proper position. A drilling machine known as a *post* or *wall radial type* is, in principle, constructed along the same lines as a plain radial drilling machine, but, instead of being provided with a base, it is arranged to be attached to a wall or post.

RADIALLY-EXPANDING CLUTCH. This is a type of friction clutch provided with shoes which are forced outward against an enclosing drum. It is the same as Internal-expanding Clutch.

RADIAN. A radian is the unit of measurement of angles in what is termed "circular measure." In practical work, angles are always measured in degrees and minutes, but, in theoretical investigations and in formulas relating to revolving bodies, circular measure is often employed. A radian is the angle at the center of a circle which embraces an arc equal in length to the length of the radius of the circle. The value of a radian in degrees equals $180 \div \pi = 57.2958$ degrees. In circular measure, π denotes an angle of 180 degrees, and $\pi \div 2$, an angle of 90 degrees. It is especially convenient to measure angles in radians when dealing with angular velocity, because, in this case, a very simple relationship is obtained between angular velocity, linear velocity, and the radius of the revolving body. This is the reason for using the radian as a unit of angular measurement. If ω = angular velocity per second of revolving body, in radians, v = velocity of a point on the periphery of a body, in feet per second; r = the radius, in feet; then $\omega = v \div r$.

RADIANT HEAT. See Conduction.

RADIATION OF HEAT. When a body is at a higher temperature than surrounding bodies, it will radiate heat to those that are of a lower temperature. The heat rays proceed in straight lines and the intensity of the heat radiated from any one source varies inversely as the square of the distance from the source. The rate at which heat is radiated by one body and

absorbed by another depends upon the temperature difference and the character of the radiating and absorbing surfaces. Dark and rough surfaces radiate and absorb more heat than smooth and polished surfaces; hence the covering of steam pipes and boilers should be smooth and of light color. Polished pipes will lose less heat than those that are left rough. The quantity of heat radiated by a body is also a measure of the amount of heat that it will absorb if it is exposed to the rays of heat. A polished surface will absorb only part of the heat and reflect the remainder, while a black and rough surface will absorb nearly all of the heat.

Use of Metallic Paint on Radiators. — In experiments made with steam and hot water radiators, coated with aluminum paint, it has been found that only about 80 per cent as much heat is conveyed into the room to be heated as when the radiators are coated with zinc oxide paint, green or white enamel, or terra cotta shellac varnish. In general, a gain of from 15 to 20 per cent in heat dissipation into a room may be expected by covering the ordinary radiator with non-metallic paint instead of with an aluminum or bronze paint. By non-metallic paint is meant a covering that does not contain flakes of pure metal, such as aluminum or bronze. If the radiator is already coated with aluminum paint, the required effect may be obtained by painting the non-metallic coating over the aluminum paint. Aluminum paint apparently is a poor radiator of heat. The non-metallic coating need not be a black paint. The white lead and zinc oxide paints and enamels, the chrome-colored pigments, and the greenish colored oxides, such as chromium oxide, offer a variety of tints for decorative purposes, with greater efficiency in heat dissipation.

RADIATOR PAINT. See under Radiation of Heat.

RADICAL IN CHEMISTRY. A radical is a group of atoms which remains unchanged during a series of chemical reactions, and hence may be regarded as replaceable by a single atom

RADICAL IN MATHEMATICS. A radical is an expression indicating a root, as $\sqrt{5}$. The " radical sign " is the root sign ($\sqrt{\ }$).

RADIO COMPASS. The radio compass or direction finder has been made in several types which differ in appearance, but depend upon the same principles. One has an outside coil mounted vertically on a spindle, rotatable in a horizontal plane, controlled by a hand wheel and fitted with a pointer. Another consists of two large fixed loops at right angles to each other, connected to a small rotating coil on the operating panel. Each is provided with the usual radio receiving, detecting, adjusting, and tuning apparatus. The pointer may be placed over the ship's magnetic compass thus giving at a glance the bearing of the radio signal station.

As the coil and pointer are rotated, the maximum intensity of sound is heard when the plane of the coil coincides with the direction to a radio signal, and the intensity gradually diminishes, reaching a minimum when the plane of the coil is at right angles. Radio waves are accompanied by a magnetic force, which is horizontal and at right angles to the direction in which the waves are traveling. Hence when the coil is on edge to the wave, it is threaded by the maximum number of magnetic lines of force, and the amplified signal is heard at a maximum. Conversely, when the coil is broadside to the direction of the transmitting station, no magnetic lines of force thread the coil and therefore no current is induced in it and no sound is heard in the receivers. At intermediate positions the current induced in the coil varies in proportion to the angle between the plane of the coil and the wave front.

To determine the position of a vessel, the navigator rotates the coil of the radio compass until the maximum signal is heard, establishing the identity of the station. He then turns the coil until the minimum intensity is reached, which is generally used for determining direction because of its more accurate definition, the coil being at right angles to the direction from which the signal comes. The pointer shows the bearing within one degree of arc.

The radio fog signal is valuable as a leading mark, to enable a vessel to make a lighthouse or lightship at the approach to a harbor. When two or more sending stations are within range of audibility, the intersection of the bearings may be laid down on a chart and the position of the vessel thus fixed. This system, for the first time in marine history, affords a practicable means by which a navigator may obtain accurate bearings on invisible objects. It not only enables vessels in a fog to determine their location relative to a harbor entrance but also to locate each other.

RADIUM. Radium is a metallic chemical element, the symbol of which is Ra, and the atomic weight, 226.4. Radium is a rare metal found only in small quantities and commanding a very high price. It is one of the most remarkable of all metals. It emits light rays which like the X-rays are invisible, but which traverse sheets of glass or metal and cannot be refracted. Radium emits three kinds of rays, which for convenience are called alpha, beta, and gamma rays. Of these, the gamma rays, which greatly resemble the Röntgen or X-rays, have tremendous penetrating power.

RADIUS OF GYRATION. The center of gyration with reference to an axis is the point at which the entire weight of a body may be considered as concentrated, the moment of inertia, meanwhile, remaining unchanged; or, in a revolving body, the center of gyration is the point at which the whole weight of the body may be considered as concentrated, the angular velocity

remaining the same. The *radius of gyration* is the distance from this point to the axis of rotation. If W is the weight of a body; I, its moment of inertia; and k, the radius of gyration, then:

$$k = \sqrt{\frac{I}{W}} \quad \text{and} \quad I = Wk^2.$$

To find the radius of gyration of an area, such as the cross-section of a beam, divide the moment of inertia of the area by the area, and extract the square root. The square of the radius of gyration of an oscillating body is equal to the product of the radius of oscillation multiplied by the distance of the center of gravity of the suspended body from the point of suspension. When the axis, with reference to which the radius of gyration is taken, passes through the center of gravity, the radius of gyration is the least possible and is called the *principal* radius of gyration. For a solid cylindrical body, such as a disk or emery wheel, the radius of gyration is equal to the radius of the disk divided by $\sqrt{2}$ or radius $\times$ 0.707. For a flywheel rim, it is sufficiently accurate to assume the radius of gyration to be the distance from the center to a point halfway between the outer and inner edges of the rim. Formulas for the radius of gyration for bodies of all ordinary geometrical shapes will be found in standard engineering handbooks.

RADIUS OF OSCILLATION. See Center of Oscillation.

RAILINGS. Railings for stairways in shop construction should be 3 feet 6 inches high. They are frequently made from pipe not less than $1\frac{1}{4}$ inch in diameter, or from angle iron not less than 2 by 2 by $\frac{1}{4}$ inch in size. All railings ten feet or more above the shop floor should be made of metal and have a toe-board at their base.

RAILS FOR RAILROADS. A rail length of 39 feet was adopted as a standard in railroad rail specifications at a convention of the American Railway Engineering Association in 1925. The 45-foot length is claimed to be the most economical and desirable, but average car lengths do not conveniently permit of their transportation, and mill facilities are not, at present, adapted to their manufacture. The reason for the use of longer rails is that joints of whatever type used constitute a heavy item of expense, both in respect to their first cost and their maintenance. By increasing the length of rails from 33 to 39 feet, the number of joints is reduced about 15 per cent.

For information concerning the minimum and maximum sizes and weights of both "light rails" and the American Railway Association's rails, see Structural Shapes.

RAKE OF METAL-CUTTING TOOLS. When a lathe or other metal-cutting tool is so ground that the surface against which the chips bear while

being severed, inclines in such a way as to increase the keenness of the cutting edge it is said to have "rake." If the inclination is such as to give the tool less keenness than is equivalent to a rake angle of zero, the term *negative rake* is often used. The amount of rake or slope that a tool should have depends upon the work for which it is intended. If, for example, a turning tool is to be used for roughing medium or soft steel, it should have a back slope of about 8 degrees and a side slope ranging from 14 to 20 degrees, while a tool for cutting very hard steel should have a back slope of about 5 degrees and a side slope of 9 degrees. The reason for decreasing the slope and thus increasing the lip angle for harder metals is to give the necessary increased strength to the cutting edge to prevent it from crumbling under the pressure of the cut.

RAM, HYDRAULIC. See Hydraulic Ram.

RANKINE'S FORMULAS. These formulas were developed for the calculation of the strength of columns. They are also known as Gordon's formulas. According to these formulas, if S = the ultimate compressive strength of the material in pounds per square inch, l = the length of the column or strut in inches, r = the least radius of gyration in inches (r^2 = moment of inertia divided by area of section), and p = the ultimate load in pounds per square inch; then for steel columns with both ends fixed:

$$p = \frac{S}{1 + \dfrac{l^2}{25{,}000\, r^2}},$$

and for cast-iron columns with both ends fixed

$$p = \frac{S}{1 + \dfrac{l^2}{5000\, r^2}}.$$

For Rankine's formulas covering other conditions of columns, and Euler's formulas for slender columns see MACHINERY'S Handbook.

RAOULT'S METHOD. This is a process for determining atomic weights based upon the discovery that the molecular weight of a compound may be determined from the changes caused in the freezing or boiling point of a liquid in which the compound is dissolved. The method can be used only with substances which have no chemical action upon the solvent.

RAPPING PLATES. Rapping plates for patterns are pieces of metal let in flush with the joint or cope side of the pattern and fastened with screws. They come in different shapes and sizes and are provided with a central hole that is tapped to receive the threaded end of a lifting iron. In addition to

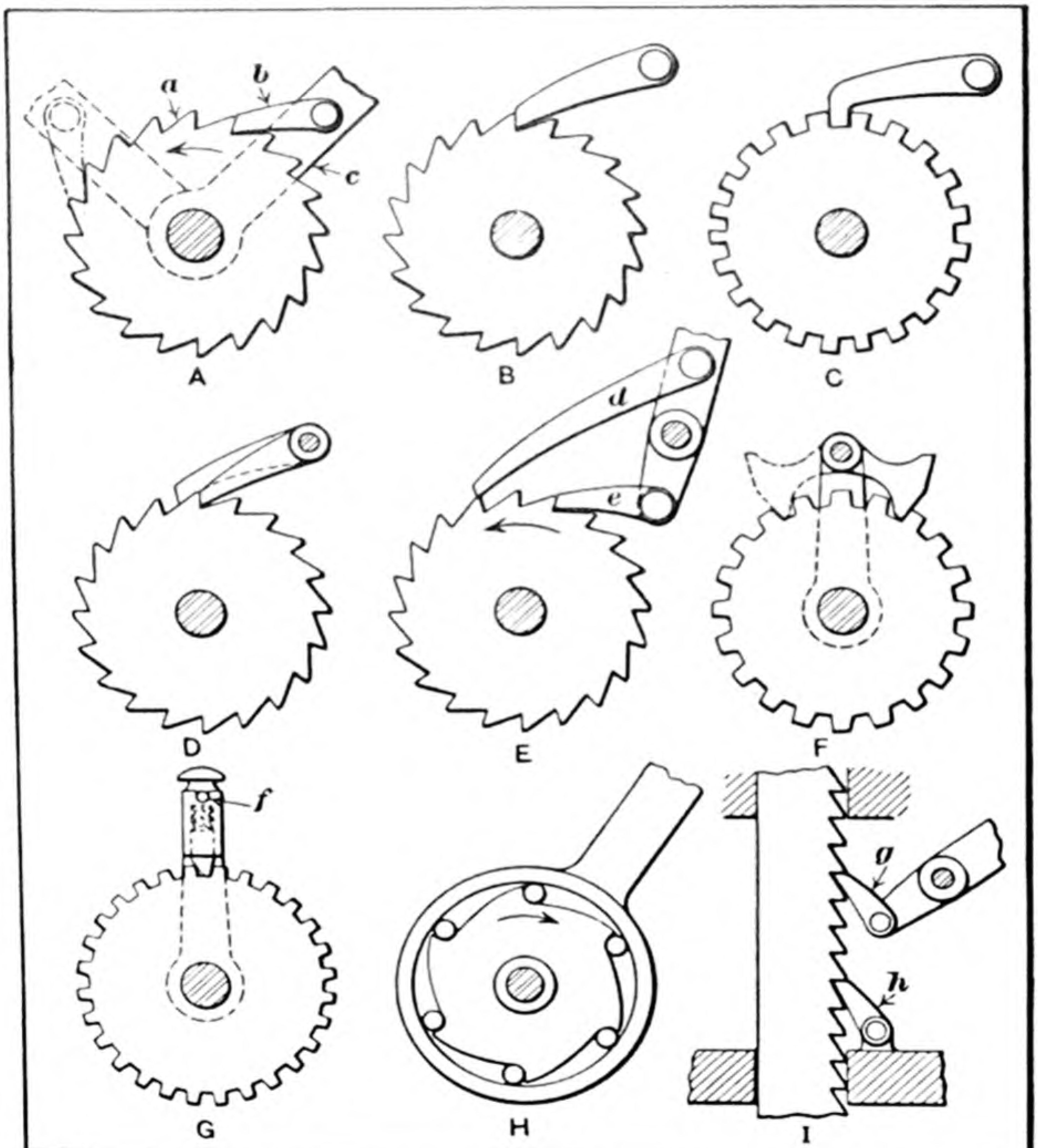
the tapped hole, there are one or more plain holes for the reception of a rapping bar. Countersunk holes are provided for fastening screws.

RASP. A rasp is a file of rectangular cross-section having teeth that are round on the top and disconnected, the teeth having been formed by raising with a punch small portions of the stock from the surface of the blank. It is used for heavy, rough filing, where a considerable amount of material is to be removed, but where a smooth surface is not required.

RATCHET DRILLS. The ratchet drill is a hand-operated tool and is generally applied to work which cannot be taken to a drilling machine. For instance, ratchet drills are often used for drilling holes in boilers, frames, bed-plates, or other heavy machine parts, especially in connection with the erection or repair of machinery and when a power-driven portable drilling machine is not available or cannot be used for lack of room. It is necessary to provide a support for the feed-screw end of the ratchet so that the drill can be forced into the metal as it is turned by a ratchet lever. In many cases, a part of the machine may be used for this purpose. If there is no rigid backing for the ratchet, the usual method is to clamp or bolt a brace or " old man " near the point where the hole is to be drilled. This brace has an adjustable arm which is clamped at the proper height, and the conical point of the ratchet feed-screw is engaged with one of the numerous center holes which are usually formed on the lower side of the arm. Some ratchet drills are designed to rotate the drill in one direction only, whereas others are reversible.

RATCHET GEARING. Ratchet gearing in its simplest form consists of a toothed ratchet wheel *a* (see diagram *A*), and a pawl or detent *b*, and it may be used to transmit intermittent motion or to prevent relative motion between two parts except in one direction. The pawl *b* is pivoted to lever *c* which, when given an oscillating movement, imparts an intermittent rotary movement to ratchet wheel *a*. Diagram *B* illustrates another application of the ordinary ratchet and pawl mechanism. In this instance, the pawl is pivoted to a stationary member and its only function is to prevent the ratchet wheel from rotating backward. With the stationary design, illustrated at *C*, the pawl prevents the ratchet wheel from rotating in either direction, so long as it is in engagement with the wheel. The principle of the *multiple-pawl ratchet gearing* is illustrated at *D*, which illustrates the use of two pawls. As will be seen, one of these pawls is longer than the other, by an amount equal to one-half the pitch of the ratchet-wheel teeth, so that the practical effect is that of reducing the pitch one-half. By placing a number of driving pawls side by side and proportioning their lengths according to the pitch of the teeth, a very fine feed can be obtained with a ratchet wheel of comparatively coarse pitch.

The type of ratchet gearing shown at *E* is sometimes employed to impart a rotary movement to the ratchet wheel for both the forward and backward motions of the lever to which the two pawls are attached. A simple form of *reversing ratchet* is illustrated at *F*. The teeth of the wheel are so shaped that either side may be used for driving by simply changing the position of the double-ended pawl, as indicated by the full and dotted lines. Another



Different Forms of Ratchet Gearing

form of reversible ratchet gearing for shapers is illustrated at *G*. The pawl, in this case, instead of being a pivoted latch, is in the form of a plunger which is free to move in the direction of its axis, but is normally held into engagement with the ratchet wheel by a small spring. When the pawl is lifted and turned one-half revolution, the driving face then engages the opposite sides of the teeth and the ratchet wheel is given an intermittent rotary motion in the opposite direction.

The *frictional type* of ratchet gearing differs from the designs previously referred to, in that there is no positive engagement between the driving and driven members of the ratchet mechanism, the motion being transmitted by frictional resistance. One type of frictional ratchet gearing is illustrated at *H*. Rollers or balls are placed between the ratchet wheel and an outer ring which, when turned in one direction, causes the rollers or balls to wedge between the wheel and ring as they move up the inclined edges of the teeth. Diagram *I* illustrates one method of utilizing ratchet gearing for moving the driven member in a straight line, as in the case of a lifting jack. The pawl *g* is pivoted to the operating lever of the jack and does the lifting, whereas the pawl *h* holds the load while the lifting pawl *g* is being returned preparatory to another lifting movement.

RATE OF COMBUSTION FOR BOILERS. The weight of coal burned in a boiler, per square foot of grate surface per hour is called the *rate of combustion.* This rate commonly varies from 12 to 25 pounds in the case of power plants operating under natural draft, increasing to 30 pounds or more when forced draft is employed. With heating boilers, the combustion is somewhat less, as it is unusual to force the boilers so much, except in large plants. Here the rate drops to 8 or 10 pounds in boilers of medium size, and to 6 or 7 in those of small size, depending upon the care they receive and the strength of chimney draft.

RATE OF EVAPORATION. The weight of dry steam evaporated in a boiler per pound of coal is called the *rate of evaporation.* This rate varies with the character of the heating surface and its relation to the grate area. In power boilers of good design, the rate of evaporation generally varies from 9 to 10 pounds, while in the case of heating boilers, it is more commonly 7 or 8 pounds.

RATIO. The *ratio* between two quantities is the quotient obtained by dividing the first quantity by the second. For example, the ratio between 3 and 12 is $\frac{1}{4}$, and the ratio between 12 and 3 is 4. Ratio is generally indicated by the sign (:); thus 12 : 3 indicates the ratio 12 to 3. A *reciprocal* or *inverse* ratio is the reciprocal of the original ratio. Thus, the inverse ratio of 5 : 7 is 7 : 5.

RATIO OF EXPANSION. The ratio of expansion in a steam engine cylinder is the reciprocal of the cut-off, that is, if the cut-off is $\frac{1}{4}$, the ratio of expansion is 4. In other words, it is the ratio of the final volume of the steam at the end of the stroke to its volume at the point of cut-off. For example, a cylinder takes steam at boiler pressure until the piston has moved one-fourth the length of its stroke; the valve now closes and expansion takes place until the stroke is completed. The one-fourth cylinderful of steam has

expanded to four times its original volume, and the ratio of expansion is said to be 4.

The most economical ratio of expansion depends largely upon the type of the engine. In the case of simple engines, the ratio is limited to 4 or 5, on account of excessive cylinder condensation in case of larger ratios. This limits the initial pressure to an average of about 90 pounds for engines of this type. In the case of compound engines, a ratio of from 8 to 10 is commonly employed to advantage, while, with triple-expansion engines, ratios of 12 to 15 have given good results.

RATIO OF SLENDERNESS. In the calculation of columns an expression "ratio of slenderness" is frequently used. This ratio is obtained by dividing the length of the column by the radius of gyration, and is simply a number which indicates the length of a column as compared with the important dimensions based upon its cross-section. The ratio of slenderness determines evidently to a considerable extent the load to which a column may be subjected. This load also depends to a large extent upon whether the ends of the column are fixed or hinged.

RATIOS, SPEED-CHANGING MECHANISMS. See under Speed-changing Mechanisms.

RAWHIDE GEARS. When a noiseless gear drive is required, rawhide is sometimes used as a material for gears. Rawhide possesses a considerable degree of toughness when properly cured. Only one of a pair of gears (generally the pinion) is made from rawhide, the other gear being made from steel or cast iron. The safe working load for a rawhide pinion of the highest grade is 150 pounds per inch width of face for one-inch circular pitch. Other pitches vary in direct proportion, except that the maximum load must not exceed 250 pounds per inch width of face. One rule for determining the pitch-line load is as follows: *To find the allowable load in pounds at the pitch-line for a rawhide pinion, multiply the width of the face in inches by from* 180 *to* 360, *and divide the product by the diametral pitch.* According to a prominent manufacturer of such gearing, a factor of about 470 should be used in place of the 180 to 360 given in the foregoing.

The raw material from which rawhide gears are made is the green packer hides, cured and treated by processes that leave mainly a fibrous structure. These processes reduce each hide to a thickness of approximately $\frac{1}{16}$ inch, the hide being then blanked into circular disks, the outside diameter of which varies from 2 to 40 inches, or into rings or segments according to the requirements of the gear manufacturer. These blanked-out hides are then dipped into a vat of special-quality glue and assembled between steel end-blocks until a thickness of about 8 or 10 inches has been reached. Hydraulic pressure is next applied to squeeze out the surplus glue, after which the

blank is kept compressed until dry, which may require several days. The pressure is increased as the drying process progresses.

RAWHIDE LACING LEATHER. The Navy Department belt specifications for rawhide belt lacing permit only hand-cut green slaughter hides of the very best quality to be used. Rawhide laces are to be in the following sizes: $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{7}{16}$, $\frac{1}{2}$, $\frac{5}{8}$, and $\frac{3}{4}$ inch. They must be cut lengthwise from the hide and have an average ultimate tensile strength not less than:

Width..................	$\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$	$\frac{1}{2}$	$\frac{5}{8}$	$\frac{3}{4}$	inch.
Tensile strength.........	95	125	155	165	180	205	230	pounds.

REACTANCE. The opposing force of self-induction to the flow of current is termed *reactance*. It is measured in ohms, the same as resistance, and also follows Ohm's law, in that:

$$\text{Current} = \frac{\text{voltage}}{\text{reactance}}.$$

Reactance may have either inductive or capacity effects, the two opposing each other. Inductive reactance causes a lagging current, and a capacity reactance, a leading current.

REACTANCE COILS. Current-limiting reactance coils utilize their counter-electromotive force of self-induction to reduce the flow of current in an alternating-current circuit. With the present tendency toward very large generating stations and units, and the concentration of large amounts of power at one place, it is evident that short circuits may give rise to very destructive effects. It therefore becomes imperative that the flow of energy in such cases be limited to a safe value, and the damaged part isolated as quickly as possible, so that the trouble will not spread to other parts of the system. The current rush is reduced by providing a sufficient amount of reactance in the circuits. In some cases, the inherent reactance of the apparatus may be increased to a value sufficiently high to limit the current to the desired value, while in other cases, it may be necessary to resort to external reactance coils.

REAGENT. A reagent, in chemistry, is any substance which is used to effect a chemical change in another substance for the purpose of chemical analysis.

REALGAR. Realgar is a compound of arsenic and sulphur (chemical formula, As_2S_2). It occurs in nature in prismatic crystals and has a specific gravity of 3.5. It is prepared artificially by fusing together arsenic and sulphur, but the resulting product varies somewhat in composition.

REAMER. Reamers are used for two purposes: (1) for producing a hole that is smooth and true to size, and (2) for enlarging cored or drilled holes.

With reference to the manner in which reamers are made, they may be divided into solid and inserted-blade reamers, the latter usually being adjustable for size. *Hand reamers* include straight reamers intended to be used by hand for producing holes that are smooth and true to size. *Fluted chucking reamers* are used in machines for enlarging holes and finishing them smooth and true to size. *Rose chucking reamers* are used in machines for enlarging cored holes and are so constructed that they are able to remove a considerable amount of metal. *Shell reamers* are provided with a hole through the center in order to save the material which otherwise would be used for the reamer shank, and are mounted by means of this hole on arbors. Shell reamers may be either of the fluted chucking or the rose chucking reamer type. *Taper reamers* are used for reaming the holes for standard taper sockets, standard taper pins, and, in general, tapered holes that must be true as regards size and taper. *Pipe reamers* constitute a large class of taper reamers; they are used for reaming taper holes previous to tapping the taper pipe taps. *Center reamers* are used for reaming the center holes in work that is to be held between the centers in different types of machine tools. *Jobbers' reamers* are similar to hand reamers and are used for similar purposes, but are provided with a taper shank so that they may be used in machines. *Taper bridge reamers* are a special type of reamers used for reaming rivet holes in structural construction work. *Grooved chucking reamers* are used for enlarging cored holes. They are fluted with spiral grooves like a twist drill and may be said to occupy a place on the boundary between reamers and drills.

Reamers used on cast iron and steel usually are fluted so that the teeth are either radial or slightly ahead of the center. If the faces of the teeth are ahead of the center, this provides negative rake, which is desirable for reamers used on brass work.

REAMER CLEARANCE. A reamer having proper clearance cuts freely and smoothly. There are three kinds of clearance, which may be described in the following order: 1. Longitudinal, which nearly all reamers should have to some extent. This is a slight taper which makes the reamer smaller toward the shank in order to prevent the back end from enlarging the hole or dragging and thereby roughing up the hole. 2. The clearance on the entering end of the teeth which every reamer ought to have. 3. The clearance along the sides of the teeth or on the peripheral part of the reamer. The latter is sometimes called radial clearance or relief.

REAMER TEETH SPACING. There are three methods of spacing reamer teeth. First, they may be spaced evenly around the entire surface; second, the spacing may be irregular but with one half of the circumference corresponding to the other half, so that the cutting edges are diametrically

opposite; and third, the spacing may be irregular around the entire circumference. The object of uneven spacing is to eliminate chatter and produce smoother holes than are obtained with uniformly spaced teeth. Some contend that a reamer spaced according to the second method is liable to chatter and that no two cutting edges should be diametrically opposite.

It is undoubtedly true that an odd number of teeth in a reamer favors smoother work than an even number of equally spaced teeth. The reason for this is as follows: In a reamer having an even number of teeth, any ridge or hard spot in the work tends to push the tooth away at that point and the action is transmitted diametrically across the reamer to the opposite side of the hole. If the reamer has an odd number of teeth, the effect is transmitted across the hole to two teeth instead of one and is, therefore, less than if concentrated on one tooth. In other words, the irregularities are not seesawed back and forth across the hole by the action of the teeth as much with an uneven number of teeth as with an even number. The average manufacturer, however, prefers reamers with an even number of teeth because of the difficulty of measuring those with an odd number of teeth. Reamers that have an even number of teeth, but with the spacing broken up so that it is irregular, can be made to ream a hole as true as an odd-toothed reamer.

RÉAUMUR THERMOMETER. The thermometer which is most commonly used for general purposes in Germany and other German speaking countries is the Réaumur thermometer, introduced about 1730 by the French scientist Réaumur. On the Réaumur scale, the freezing point of water is located at 0, and the boiling point of water, at atmospheric pressure, at 80 degrees. The following formulas may be used for converting temperatures given on the Réaumur scale to temperatures on the Centigrade and Fahrenheit scales:

$$\text{Degrees Réaumur} = \frac{4 \times \text{degrees C.}}{5}.$$

$$\text{Degrees Réaumur} = \frac{4 \times (\text{degrees F.} - 32)}{9}.$$

For scientific work the Centigrade scale is used almost exclusively in all countries.

RECALESCENCE POINT. The recalescence point, sometimes designated Ar. 1, is the temperature at which the internal structure of steel which has been heated above the decalescence point and then allowed to cool slowly, changes back to the structural condition existing before the steel was heated above the decalescence point. When a piece of steel has been heated above the hardening temperature and is permitted to cool slowly, its temperature falls uniformly until the recalescence

point is reached, but here the internal changes of the carbon and iron that take place evolve a certain amount of heat, so that the temperature remains stationary for a short time, and sometimes even rises slightly. After the internal changes have taken place, the steel will continue to cool off gradually. The recalescence point for different kinds of steel varies, but is about from 1325 to 1400 degrees F.

RECARBURIZING. Recarburizing is the process of adding carbon to the charge in a Bessemer converter. The usual recarburizers are ferro-manganese, spiegeleisen, ferro-silicon, and silico-spiegel.

RECEIVER, AIR. See Air Receiver.

RECESSING TOOL. A recessing tool is a cutting tool intended for cutting an internal groove or recess in a machine part. Recesses are often cut on the inside of castings and forgings in places which may be rather inaccessible. Special tool-holders and devices, all of which are generally classified as " recessing tools," are sometimes used for this purpose.

RECTIFIERS. Mercury arc rectifiers serve the purpose of rectifying alternating currents, *i.e.*, changing it into direct current. All types of mercury arc rectifiers have three essential parts: 1. The rectifier tube. 2. The main reactance. 3. The operating equipment. The following are some of the uses to which various types of rectifiers may be put: 1. Storage battery charging in electric automobiles, in telephone systems, for railway signals, on telegraph lines, for operating oil and miscellaneous switches, for gas and gasoline engine ignition, and for dental and small motors. 2. Arc lamp operation in moving-picture machines, in photo-engraving, in theatre, spot, and flood lamps, in factory and street lighting. 3. Operating motors. 4. Electrolytic baths. 5. X-ray coils.

RECTILINEAR CRANE. This is a crane in which the load is first moved in a straight line in one direction and then in a straight line in a direction at right angles to the first. The over-head traveling crane is an example of this type. Some rectilinear cranes are provided with movement for the load in one direction only.

RED BRASS. The alloy known as " red brass," contains 85 per cent of copper, 5 per cent of tin, 5 per cent of lead, and 5 per cent of zinc. This is the recognized standard red brass. There are numerous modifications, for various purposes. A metal used widely for pump bodies, valves, and similar parts, known as *red composition* or *ounce metal* has the same composition as red brass. For general service, this is regarded as an excellent bearing metal.

RED HARDNESS. A term sometimes applied in connection with high-speed steel because of its property of retaining a sufficient hardness for

cutting metals even when heated to a temperature high enough to cause dull redness. The property of red hardness is conferred upon the steel by the presence of tungsten and by the heat-treatment to which it is subjected. See High-speed Steel.

RED HEMATITE ORE. See Hematite Ore.

RED LEAD. Red lead is a bright red pigment made either by oxidizing litharge in furnaces or by heating it with sodium nitrate in iron pots. The color varies somewhat according to the conditions of manufacture and other details. It is widely used for the protection of iron, and is considered to be one of the best pigments known. It is generally mixed with oil, when required for use, in the proportion of 30 pounds of pigment to a gallon of oil. It exerts such a drying action on the oil that no other drier is necessary. Sulphurous gases tend to turn it brown, and it is often mixed with certain inert materials.

REDUCER. Reducers may be classified as follows: (1) A fitting having a larger size at one end than at the other. Some have tried to establish the term "increaser" — thinking of direction of flow — but this has been due to a misunderstanding of the trade custom of always giving the largest size of run of a fitting first; hence, all fittings having more than one size are reducers. They are always threaded inside, unless specified flanged or for some special joint. (2) Threaded type, made with abrupt reduction. (3) Flanged pattern with taper body. (4) Flanged eccentric pattern with taper body, but flanges at 90 degrees to one side of body. The term reducer is misapplied at times to a reducing coupling.

REDUCING AGENT. This term is applied to a substance that removes oxygen or elements similar to it. See Oxidizing and Reducing Agents.

REDUCING PRESSES. Reducing presses are used for reducing in diameter cups or shells previously cut and formed in double-action presses, in order to form tubes which may vary more or less in length. Reducing presses are used more especially in the manufacture of such articles as cartridges, ferrules, pencil tubes, pencil cases, pen holders, burner tubes, and large variety of other articles made of brass and silverware. These presses are also extensively used for forming, bending, and finishing operations on deep work. They are built in different types and sizes and, in some cases, have automatic dial feeding mechanisms.

REDUCTION OF AREA. See Elongation and Reduction of Area.

REFERENCE GAGES. Reference gages are made to test or check the dimensions of inspection gages. The tendency is toward reducing the cost of gaging systems by making reference gages only when standard measuring

plugs or other simple and accurate measuring means cannot be conveniently used. When a comparatively small number of pieces are to be made, it is also more economical not to make reference gages. When the inspection gages and working gages are made to different tolerances, reference gages are not provided for the working gages, due to the fact that it would require a separate set of reference gages, which is unnecessary and which would merely involve an additional expense.

Reference gages are generally made the reverse or opposite to the inspection gages; that is, female reference gages are made for male inspection gages, and *vice versa*. As a rule, it is best to make the reference gages so that they fit the gaging and locating surfaces of the inspection gage to the same extent that the work fits the inspection gage. In this way, wear of the gage is more easily detected. It is not customary, however, to make a ring gage as a reference gage for a plug inspection gage, but a snap gage is used instead. The reference gage for a snap inspection gage, again, is usually a cylindrical plug gage, not a flat plug gage. By a flat plug gage is meant a plug gage that is rectangular in cross-section.

While it is the general practice to make reference gages opposite to the inspection gages, this is not always the case. It is, for example, most convenient to compare a plug gage with another plug gage, and this holds true especially with thread gages, because it is much easier to compare the diameters of a plug thread gage with another plug thread gage than to do the checking with a ring gage.

While a reference gage for a snap gage will have both maximum and minimum limits, the general practice is to make only one reference gage for contour gages, flush-pin gages, and similar types, in order to minimize the expense. The reference gage in that case ought to be made to correspond to the basic or, generally speaking, to the maximum metal dimension on the drawing of the component part for which the gages are used.

REFRIGERATION. The three standard systems of mechanical refrigeration are the dense-air system, the compression system, and the absorption system. *The dense-air system* is so called because the air, which is the refrigerating medium, is never allowed to fall to atmospheric pressure, in order to reduce the size of the cylinders and pipes through which a given weight of air may be circulated. This process does not depend upon the liquefaction of the air, as it is not liquefied but simply compressed and expanded adiabatically. The dense-air process is based upon the fact that a perfect gas under pressure, expanding adiabatically and performing external work will suffer a drop in temperature proportional to the mechanical energy produced. *The compression system*, using ammonia, carbon dioxide, sulphur dioxide, ethyl chloride, methyl chloride, etc., employs a compressor to raise the pressure of the vapor and deliver it to the condenser and there liquefy it,

after removing it from the evaporator or expander. *The absorption system,* using ammonia, is so designated because a weak water solution removes the vapor from the expander or evaporator by absorption. The richer aqua ammonia so formed is pumped into a high-pressure chamber (called a generator) in communication with the condenser where the ammonia is discharged from the liquid solution, or rich liquor as it is called, to the condenser by heating the generator, to which the solution is delivered by the only moving part in the process, namely, a slow-moving pump.

REGENERATIVE BRAKING. When regenerative braking is used on an electric motor (either direct- or alternating-current), the motor is connected for the desired direction of rotation as a separately excited generator to a constant voltage supply system, and if the machinery to which the motor is connected attempts to drive it at greater than full speed, it will generate electric power and supply it to the power system in the same way as a central station generator would do. This regenerative electric power causes the motor to produce a holding back or braking effect on the machinery to which it is connected. See Dynamic Braking.

REGENERATIVE CYCLE. This term is used in steam engineering, and the cycle is called " regenerative " because steam is bled from a steam turbine at a number of stages to feedwater heaters, and the heat which is thus recovered is returned to the boiler.

REGULAR LAY. This term indicates the direction of twist in wire ropes. In ropes having regular lay, the wires of the strands are twisted in one direction and the strands are laid into the rope in the opposite direction. This type of rope, in the United States, at least, may be considered as the standard.

REGULATING POLE CONVERTER. This is a synchronous converter used for producing a variable direct-current voltage. The regulating pole converter differs from the ordinary converter in that the field poles are divided into two parts, a main pole and a regulating pole. The ratio between the direct- and the alternating-current voltages may be changed by varying the excitation of the regulating poles by using a field rheostat for controlling the exciting current.

REHEADER. A reheader is a cold-heading machine in which pieces that have been partly formed in an ordinary heading machine are completed. By means of an automatic hopper feed, the pieces are placed in the heading dies and the subsequent operations performed.

REINFORCED CONCRETE. Reinforced concrete consists of concrete in which steel bars of various forms, or special forms of steel wire mesh are imbedded. The object is to make concrete able to resist tensile stresses as

well as compressive stresses. The steel bars are usually fixed at the ends by being built into columns, walls, etc., and should preferably be continuous from the immediate supports.

RELATIVE VELOCITY. The rate of motion of a body with relation to another moving body is the relative velocity, the term being used to distinguish between relative and absolute velocity, the latter being the velocity of a body with reference to some object which is considered completely at rest. The piston of a locomotive cylinder has a relative velocity with reference to the cylinder walls, but its absolute velocity is its rate of motion with reference to the rails and equals that of the train plus or minus the relative velocity of the piston with reference to the cylinder, the relative velocity being added to the train velocity when the piston moves in the direction of the train, and subtracted from the train velocity when the piston moves opposite to the motion of the train.

RELAYS. A relay is an electrically operated device used in connection with the automatic tripping of circuit-breakers or oil switches when predetermined abnormal conditions occur. Oil switches and air-break circuit-breakers that are tripped automatically are provided with alternating- or direct-current trip coils to which the contacts of the relays may be electrically connected, or with tripping mechanisms on which the movable part of the relay may act directly. The usual purpose of a relay is to assist in disconnecting that part of an electrical system in which a fault has occurred, from the rest of the system, with the least practicable delay; and to limit such disconnecting to that part of the system that is in trouble. Relays, however, are used for other purposes, such as for signaling; for controlling the operating current of solenoids, motors, etc., and thus reducing the amount of current to be broken by the control switch and the size of leads run to the switchboard; for bell alarm or lamp indication of the automatic operation of oil switches or circuit-breakers; and for electrically interlocking switches or circuit-breakers. Relays are divided into two general classes: Direct-current relays and alternating-current relays.

RELIEF OF TAPS. A tap is said to be relieved when the portions of the land back of the cutting edge are so cut away that the heel of the land is nearer to the axis of the tap than is the cutting edge. The object of this relief is to enable the tap to cut more freely, by giving it a keener cutting edge, and by reducing to a minimum the friction between the teeth of the tap and the work being tapped. It is apparent that taps may be relieved both on the outside diameter and in the angle (and then also at the root) of the thread, or they may be relieved only on the top of the thread, but not in the angle (or at the root) of the thread. A number of different methods have been used for relieving straight or non-tapering taps. In many in-

stances, no relief at all has been given to the full threads, but the tops of the threads of the chamfered portion at the end of the tap have been relieved in a manner similar to that used for milling cutters. In other instances, the thread has been relieved both on the top and in the angle, clear from the cutting edge to the heel.

The method of relieving the tap both on the top and in the angle of the thread clear from the cutting edge to the heel has the objection that the tap will lose its size as soon as it is ground on the face of the cutting edge which is the correct method of sharpening. Furthermore, it is claimed that taps thus relieved cannot cut a perfectly round and smooth hole, because they are not sufficiently supported while cutting, as the surface of contact between the tap and the work is practically limited to a number of points. To overcome the objection of having only point supports, taps have been manufactured with relief in the angle of the thread only, while the outside was left the full diameter of the thread from the cutting edge to the heel.

On account of the many objections to the various kinds of relief on straight-threaded taps, most manufacturers have adopted the practice of providing their taps with " back taper;" that is, the diameter of the thread both in the angle and on the outside is made a very small amount less at the end of the thread joining the shank than at the point. When taps are made in this way, the cutting size of the tap will be at the large end of the chamfered portion. At the shank end of the thread, the diameter will be anywhere from 0.0005 to 0.0025 inch smaller than at the point, according to the size of the tap.

RELIEVING. Relieving, also known as *backing off*, is the process of removing, by turning, grinding, or milling, some of the metal behind the cutting edge of a cutting tool in order to provide clearance; applied specifically to milling cutters, taps, dies, reamers, and drills. Many milling cutters for gear cutting and form milling are so relieved that the cutting edges retain the same shape or curvature as the front faces of the teeth are ground repeatedly for sharpening.

RELIEVING ATTACHMENTS. A relieving attachment is a device applied to lathes (especially those used in tool-rooms) for imparting a reciprocating motion to the tool-slide and tool, in order to provide relief or clearance for the cutting edges of milling cutters, taps, hobs, etc. For example, in making a milling cutter of the formed type, such as is used for cutting gears, it is essential to provide clearance for the teeth and so form them that they may be ground repeatedly without changing the contour or shape of the cutting edge. This may be accomplished by using a relieving attachment. The tool for " backing off " or giving clearance to the teeth corresponds to the shape required, and it is given a certain amount of

reciprocating movement, so that it forms a surface back of each cutting edge, which is of uniform cross-section on a radial plane but eccentric to the axis of the cutter sufficiently to provide the necessary clearance for the cutting edges.

RELUCTANCE. The magnetic resistance in a magnetic circuit is termed *reluctance*, and the unit of reluctance is expressed in *oersted*. Reluctance corresponds exactly to electrical resistance and is the force opposing the magnetic flux. The reluctivity or specific reluctance corresponds to specific resistance and is the reluctance per centimeter cube of the material forming any part of the magnetic circuit. The reciprocal of reluctance is *permeability*.

RENOLD CHAIN. This is a type of silent driving chain known by this name from the inventor. The plates of the chain are made from heavy gage material of high tensile strength, and each plate is fitted with circular case-hardened bushings. These bushings are slightly longer than the thickness of the plates and project a little beyond each face of the latter, thus preventing the plates from binding against one another. This construction reduces the bending friction and facilitates lubrication. See Silent Chain Transmission.

REPEATED-STRESS TESTS. With the repeated-stress method of testing, a test specimen is held firmly, and a load not sufficient to rupture it is applied, released, and applied again, this procedure being rapidly repeated a large number of times; or the specimen may be strained in one direction, released, and strained in the opposite direction, then released again and strained in the first direction, this procedure being repeated a great number of times. A record is made of the method of loading and the number of alternations necessary to cause breakage or, as it is commonly termed, "failure." The object of repeated-stress tests is to determine as nearly as possible the probable action or life of a given material under assumed working conditions. The methods used vary greatly.

REPLACEMENT VALUE. The replacement value of a machine or other unit is the actual cost of replacing the unit with one of the same type, at prevailing market prices at the time of appraisal. Replacement value, then, is the market price with freight and cost of installation added. In the case of large machine tools, the freight and installation items are large enough to be well worth considering, especially when expensive foundations are necessary. In appraising medium-size machinery, an allowance of five per cent of the market price of the machine is made to cover freight and ten per cent to cover installation. In appraising small parts of machinery and small tools, these items are practically negligible when considering individual tools.

Of course, in appraising the contents of a tool-room, where large quantities of tools have been purchased in bulk, some allowance should be made for freight.

RESISTANCE. Resistance is the property of a substance that opposes the flow of an electric current. The practical unit of resistance is the ohm, which equals the resistance of a column of mercury 106.3 centimeters high, 14,452 grams in mass, of constant cross-section, and at a temperature of 32 degrees F. The electrical resistance of a conductor varies directly with its length and inversely with its cross-sectional area. For metal conductors, it also increases with the temperature. The "specific resistance" is the resistance per mil-foot of a material; it is also sometimes termed "resistivity."

RESISTANCE, AIR. See Air Resistance; also Air Resistance, Racing Car.

RESISTANCE MATERIALS, ELECTRICAL. See Calido; also Silundum.

RESISTOR. A resistor limits the current in an electric circuit by transforming a portion of the electrical energy into heat, which may be stored temporarily in the resistor, but is ultimately dissipated to the surrounding medium, which is usually the atmosphere. It is the basis of nearly all controlling devices and is made in the following different types: The tube type, which consists of a tube of fireproof insulating material on which the resistance wire is wound; the bar type, which consists of a flattened tube or an iron bar insulated with a fireproof material on which the resistance wire is wound; the ventilated wire type, which consists of an insulated support on which the resistance wire is wound; the edgewise type, which consists of a conductor of narrow ribbon wound edgewise on a suitable mandrel, after which it is dipped in a thin mixture of fireclay or other fireproof insulating material; the plate type, which consists of a molded plate of insulating material in which the resistor wire is imbedded, the contact points projecting through the surface of the plate; the cast-iron grid type, which consists of a special grade of cast iron of suitable shape, so as to insure sufficient length and mechanical strength. The property of dissipating the absorbed energy by the transference of heat to the surrounding medium is known as the "radiating capacity," and the property of absorbing energy by storing it in the form of heat, as the "thermal capacity" of the resistor.

RESOLUTION OF FORCES. This expression, which is used by mechanics, relates to the finding of two or more components of a given force. See Force.

RESONANCE. In electric circuits containing resistance, inductance, and capacity, a condition may exist so that the positive reactance of the

inductance is equal in value to, and is neutralized by, the negative reactance of the capacity. This is called a *resonance condition*, under which the current flow with a given electromotive force is limited solely by the resistance of the circuit. For small resistance values, the current may, therefore, reach very high values.

RETURN TRAPS. Return traps are used for returning the water of condensation from a heating system back to the boiler, and for handling the water from both open and closed heaters. The principle of operation is that of allowing water under a low pressure to enter a chamber elevated above the boiler, and, when filled, of closing the connection with the low-pressure system and admitting steam at boiler pressure, thus causing the water to flow into the boiler by gravity. These operations are all automatic.

REVERSE-CURRENT TRIP. A reverse-current trip is an arrangement for tripping a circuit-breaker when the current flowing through the circuit in a direction the reverse of that in which it flows under normal conditions, has reached a predetermined value. The tripping may be accomplished by either the attracting or the releasing of the armature of the magnetic circuit, depending upon the arrangement of the series and potential coils. It will be easily understood that the direction of current in the potential coil will always be the same, regardless of whether the current is flowing from a generator to a battery, or from a battery to a generator, and tending to motor it. On the other hand, the direction of the current in the series coil will be reversed under similar conditions.

REVOLUTION COUNTER. See Speed Indicators.

REX. Rex is the trade name for an aluminum oxide abrasive which is used for grinding either soft or hardened steel. Rex is a product of the electric furnace, the process of manufacture being similar to that of alundum.

RHEOSTAT. Resistances in electrical circuits can be made adjustable in a number of ways. One way is by short-circuiting sections of a resistance; another way is by shifting the terminals so as to include between them more or less resistance. A resistance device that is used for controlling electric current is called a *rheostat*; these instruments are usually adjustable. A *rheostat switch* is usually a part of the rheostat and consists of an insulating base on which are mounted, on the circumference of the circle, a number of stationary contacts and an arm pivoted at the center of the circle which carries a contact that makes connection with the stationary contacts. The stationary contacts are connected to various sections of the resistance of the rheostat, and the switch is used for cutting these sections of resistance in and out of circuit. A convenient form of rheostat, when large currents are to be controlled, is the *water rheostat*, which is usually a tank containing a

solution of either salt or soda in which metal plates are suspended. The resistance of the rheostat is controlled by the depth to which the plates are submerged. See Motor Speed Regulation; also Motor Starters.

RICE COAL. Rice coal is of such size that the pieces will not pass a screen of $\frac{3}{16}$-inch mesh, but pass a screen of $\frac{3}{8}$-inch mesh. Rice coal is often used for power plant purposes.

RIDDLES. A molder's sieve is called a " riddle." The riddles are made in various degrees of fineness as determined by the number of openings per inch in the wire mesh. Power riddles are largely used for sifting and mixing sand. There are many different types of riddles which are driven by belt, compressed air, and electricity.

RIEDLER PUMP. The difficulty of operating pumps at high speed when they are equipped with ordinary self-closing valves in the pump cylinder is due to slip and frictional resistance, resulting from the flow of the water through the valves at high velocity. The Riedler pump (invented by Prof. Riedler) is designed especially for high-speed operation. One large valve is used instead of a number of small ones, thus decreasing the friction of the water in the valve passages. The first pump equipped with Riedler valves was constructed in 1884. The suction and discharge valves are practically the same and are composed of three concentric bronze rings, which serve to open and close a like number of concentric openings in the valve-seat. The valves have a high lift and the area through them is such as to reduce the velocity of the water enough to prevent excessive frictional resistance. The closing of the valves is positively controlled by an eccentric which transmits motion through an oscillating wrist plate and connecting-rods. The valves open automatically and remain open during practically the entire stroke, and then the closing is effected quickly and positively by the valve-gear. These pumps are adapted to various classes of service as well as for large capacities and high pressures.

What is known as the Riedler *express pump* is designed for much higher speeds than the ordinary type, and differs from the latter in regard to the arrangement and operation of the valves. The suction valve is the principal feature. This valve is concentric with the plunger and is annular in form.

RIFFLERS. Rifflers are small bent files which may be obtained in a large variety of shapes, sizes, and cuts. In use, the riffler is held lightly in the hand and is worked back and forth over the surface to be smoothed; thus, it is filing on a small scale. The most common form is the " spoon " riffler, which comes in many different grades of curves, its name describing its shape perfectly. Next in point of usefulness is the flat riffler, which is made in different shapes and widths to take care of the flat surfaces and panels in the

die impressions. Other styles are the "hook" riffler, the "knife" riffler, and the "round taper" riffler.

RIN. A Japanese measure of weight equal to 0.0375 gram or 0.579 grain. One rin equals 10 mos.

RING OILING. The ring method of oiling a bearing is so named because the oil is carried from a reservoir in the base of the bearing, up over the journal or shaft, by a loose-fitting ring which receives a rotary motion as the shaft revolves. The lower section of this ring is immersed in the oil so that the entire ring is flooded whenever it is revolved. The two sectional views (Fig. 1), give an example of a long bearing (for a disk grinder), with a ring,

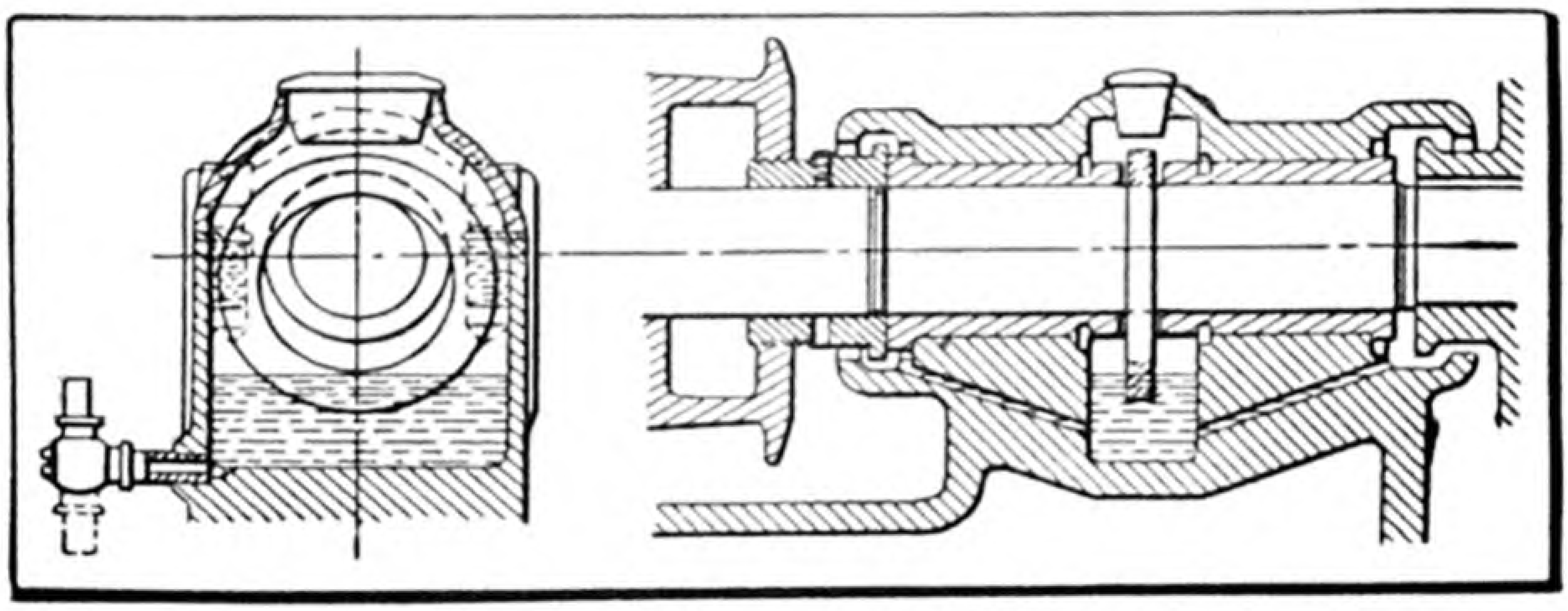


Fig. 1. Ring-oiled Bearing

and grooved bearing brasses. A well is cored out and has a draining pipe, which is turned downwards to empty the well. When in the vertical position indicated, the well is filled until the pipe is filled nearly to the top, and the inlet is then plugged. The square shoulders on the pulley collar and the disk throw the oil off into the annular recesses whence it drains down into the well. No ribs or other projections should be fitted on the rings, as such arrangements produce a resistance to their passage through the oil bath, and bring them to a standstill. At high speeds, the centrifugal force renders the flow of oil from the ring to the journal difficult, and scrapers are used for diverting the oil into the oil channels. These, however, should never touch the ring, as they will then stop its motion. Self-oiling bearings having rings fast on the shaft are not much used.

Oil-ring Design. — As an oil-ring-lubricated journal must be started dry or nearly dry, an oil-ring should be so designed that it will start promptly when the shaft begins to rotate. After the ring has once started, it should continue to rotate as long as the shaft turns. On a poorly designed bearing, it is not uncommon to see a ring start, stop, and repeat this action in regular cycles. When the oil gets on the ring, the coefficient of friction drops rapidly, but it should still remain high enough to rotate the ring. Other causes of rings sticking are unbalance in the rings due to blow-holes, lumps of

solder, unsymmetrical design, or egg-shaped rings. As a general rule, the oil-ring should be made at least twice the diameter of the shaft. The oil cellar should be so proportioned and the oil overflow so located that, with a maximum oil level, the ring will dip into the oil to a depth equal to about one-third the diameter of the shaft. A ring should be heavy enough to stand up under production cuts.

The cross-sectional shape of the ring is important. A plain rectangular cross-section, such as shown at *A* (see Fig. 2), is often used. Rings of this kind can be easily machined from tubing. A better shape than the rectangle for the cross-section of an oil-ring is the trapezoid shown at *B*. It is sometimes necessary to have a ring fit the slot rather closely, and this shaped ring is less likely to bind in the slot if the machine happens to be a little out of level axially. A further refinement may be made by chamfering the bore as at *C*. For small light rings, this is particularly good, as it increases the specific pressure between the shaft and ring, thus enabling the ring, even

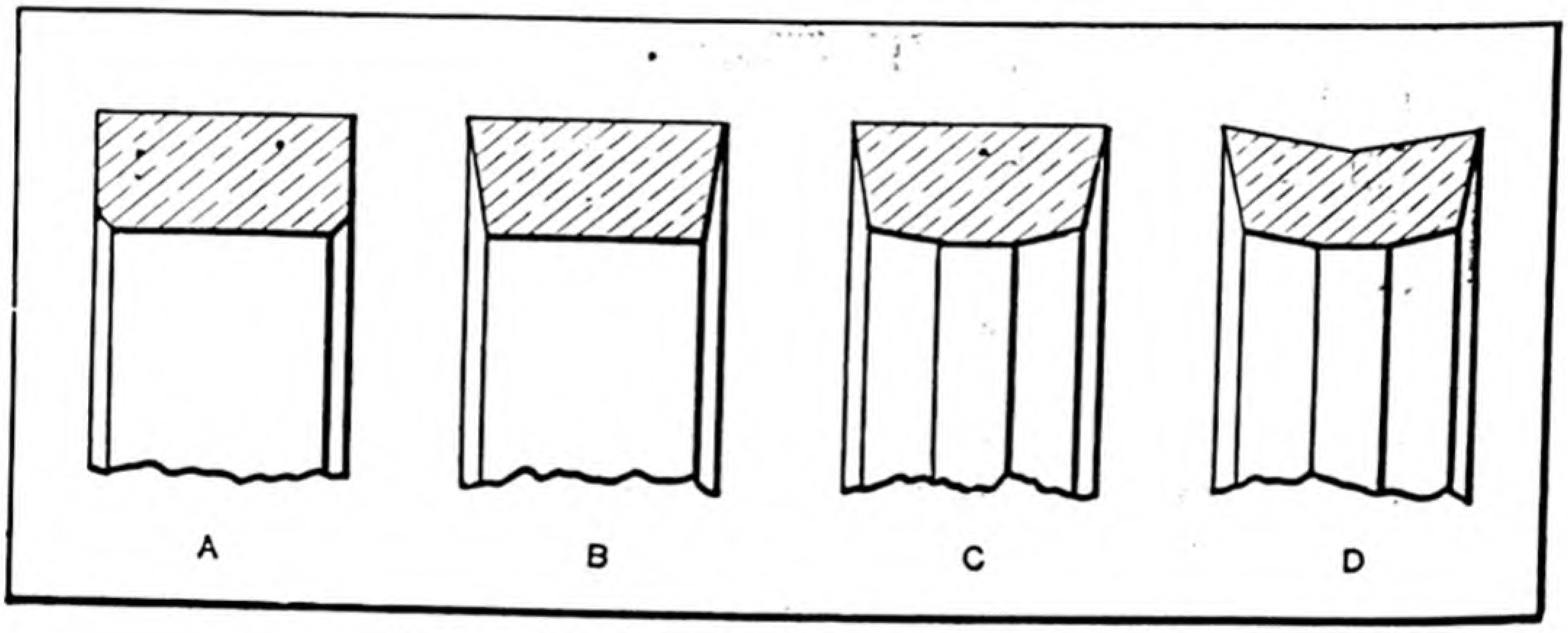


Fig. 2. Oil-rings of Different Cross-section

though light in weight, to cut through the oil and get a better bite on the shaft. The contour of the cross-section shown at *D*, effectively prevents oil-throwing. The oil collects at the two outer edges, and when thrown off, strikes the sides of the oil-ring slot, which prevents it from leaving the pedestal.

A fairly hard brass is a desirable material for small and medium sized oil-rings. Cast iron has been used with success, but this is not generally favored. It is claimed that washers of sheet metal, several of them running in one ring slot, have given satisfactory results. Very soft compositions or dead soft brass should be avoided, for if the oil becomes gritty, the rings will be charged like a lap, and will wear grooves in the journal.

RING SPRING. The ring spring is so named because it consists of inner and outer solid rings which fit into each other along conical surfaces. This spring is so designed that when axial pressure is applied the outer rings are

subjected to tensile stresses and the inner rings to compression stresses, these stresses always being within the elastic limit of the material. On account of the deformation of the rings which occurs, they slide into each other and a spring action is obtained in the direction of the longitudinal axis of the spring. Relative motion of the rings is also opposed by considerable frictional resistance between the conical surfaces which materially increases the spring reaction during compression, and exerts a retarding action during the recoil when the load is released. Springs of the ordinary form are subjected to bending or torsion, whereas the ring spring is subjected only to tension and compression stresses, which results in a much more effective utilization of the material. The friction between the ring sections increases the amount of work done during compression to about five times that of ordinary springs allowing the same maximum stress of the material. Hence, it is possible by the use of ring springs, especially if they are arranged one within the other, to form a spring that will accumulate a large amount of energy; however, only about one-quarter of the energy absorbed is returned during recoil.

RING-WHEEL GRINDERS. Grinding wheels of the ring type are applied to disk grinders for many operations, instead of using the regular steel disks faced with abrasive cloth. These ring wheels, which are held in special chucks, are especially adapted for operations requiring the grinding of a comparatively large amount of stock, or when water cooling is necessary. When ring wheels are used, the work is usually held rigidly and is fed across the face of the grinding wheel by an oscillating movement of the work-table. The wheels used are bonded by the vitrified process, and carbide of silicon abrasives, such as carborundum, crystolon, etc., are ordinarily used for such metals as cast iron and brass, while aluminum-oxide abrasives, such as alundum and aloxite, are used for steel or malleable iron parts.

RING-WOUND ARMATURE. In electric generators or motors, a ring-wound armature is an armature in which the conductors are laid side by side and connected by threading the wire through the center of a ring-shaped armature core. This type has been superseded by the "drum-wound armature."

RISERS AND FEEDERS. Risers are openings in molds, similar to pouring gates, in which the metal rises and floats the dirt out of the mold. They should be placed where the dirt is most likely to accumulate. On large castings where there is considerable shrinkage, the riser is made large in order to supply metal to compensate for the shrinkage, and is known as a *feeder*, *header*, or *shrink-head*. The riser or feeder must be large enough so that it will not set before the casting. Linings and rolls are sometimes made longer than necessary in order to feed the shrinkage and catch the dirt.

The surplus metal is called a *sinking head* and is cut off in the machine shop. A riser is not required when the dirt and shrinkage are taken care of in this way.

RIVETS. Rivets are used as permanent means for fastening or joining together parts of metal structures. There is a head on each end of the rivet, one head being formed after assembling the parts, either by the application of pressure or a succession of blows. The form of the head varies, but is generally spherical or conical, the apex of the cone usually being cut off so that the head has the shape of a frustrum. Sometimes the head is countersunk in the plates held together by the rivet. Fig. 1 shows a number of

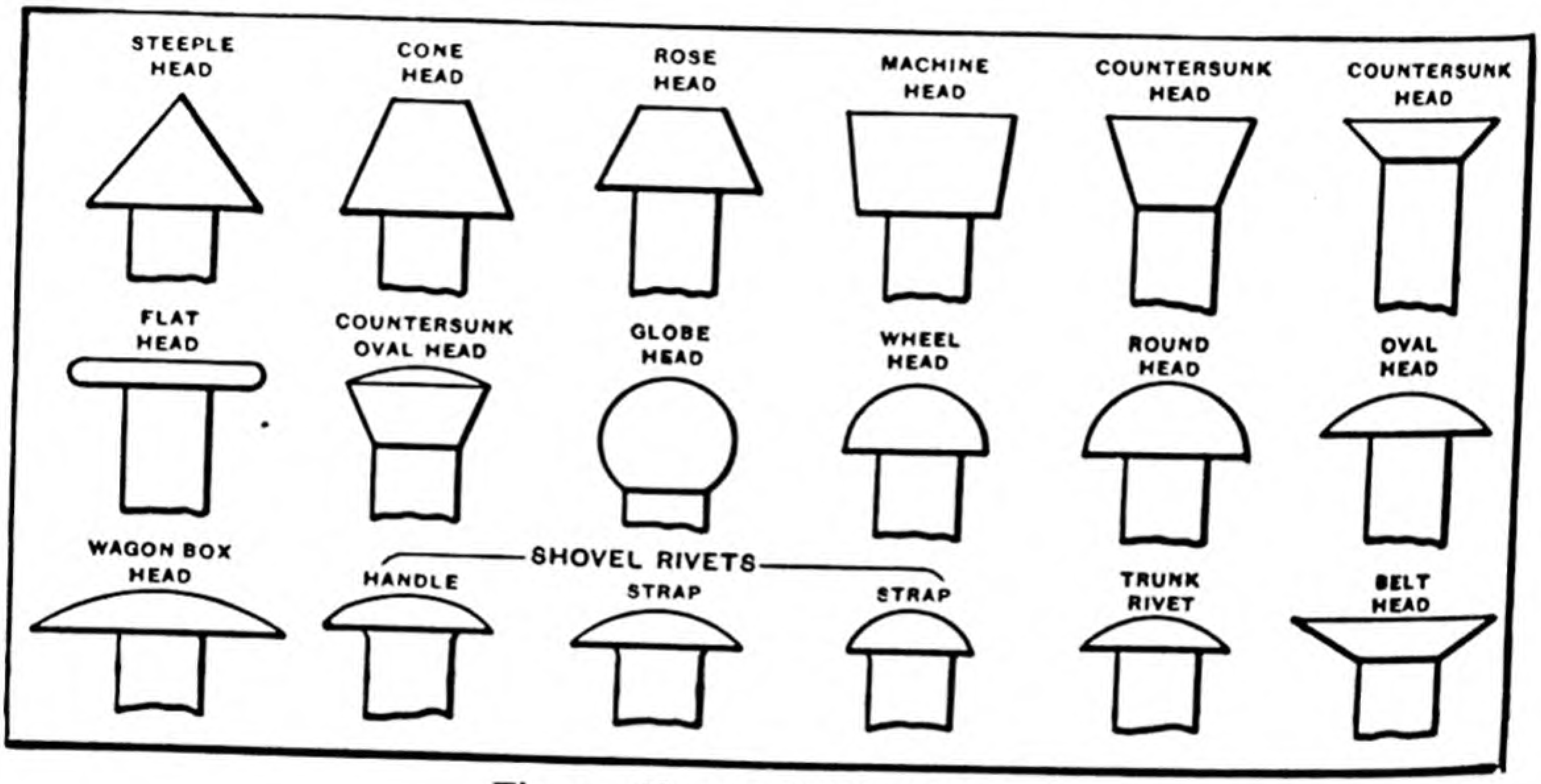


Fig. 1. Names of Rivet Heads

different types of rivet heads. In order to form the head and fill the clearance space in the rivet hole, the rivet should have a length in excess of the thickness of the plate equal to about three-fourths the diameter for the countersunk head, and from 1.3 to 1.7 times the diameter for ordinary riveting. It is advisable to make the rivets of the same material as the plates in which they are used, to prevent corrosion from galvanic action; that is, iron rivets should be used for iron plates, steel rivets for steel plates, and copper rivets for copper plates.

The proportions adopted by the American Boiler Manufacturers Association for the common types of rivet heads, are as follows: *Steeple head:* Diameter A (see Fig. 2) of the head equals twice the rivet diameter D, and height C of the head is equal to diameter D. *Button or round head:* Diameter A of the head equals 1.75 times rivet diameter D, and height C of the head equals 0.75 times diameter D. *Cone head:* The large diameter A of the head equals 1.75 times rivet diameter D, the small diameter B equals

0.9375 times diameter D, and the height C equals 0.875 times the diameter D. *Countersunk head:* The diameter A of the head equals 1.839 times rivet diameter D, and the height K equals 0.5 times diameter D. The included angle of 80 degrees has been adopted by the American Boiler Manufacturers Association for countersunk rivet heads. According to the handbooks of

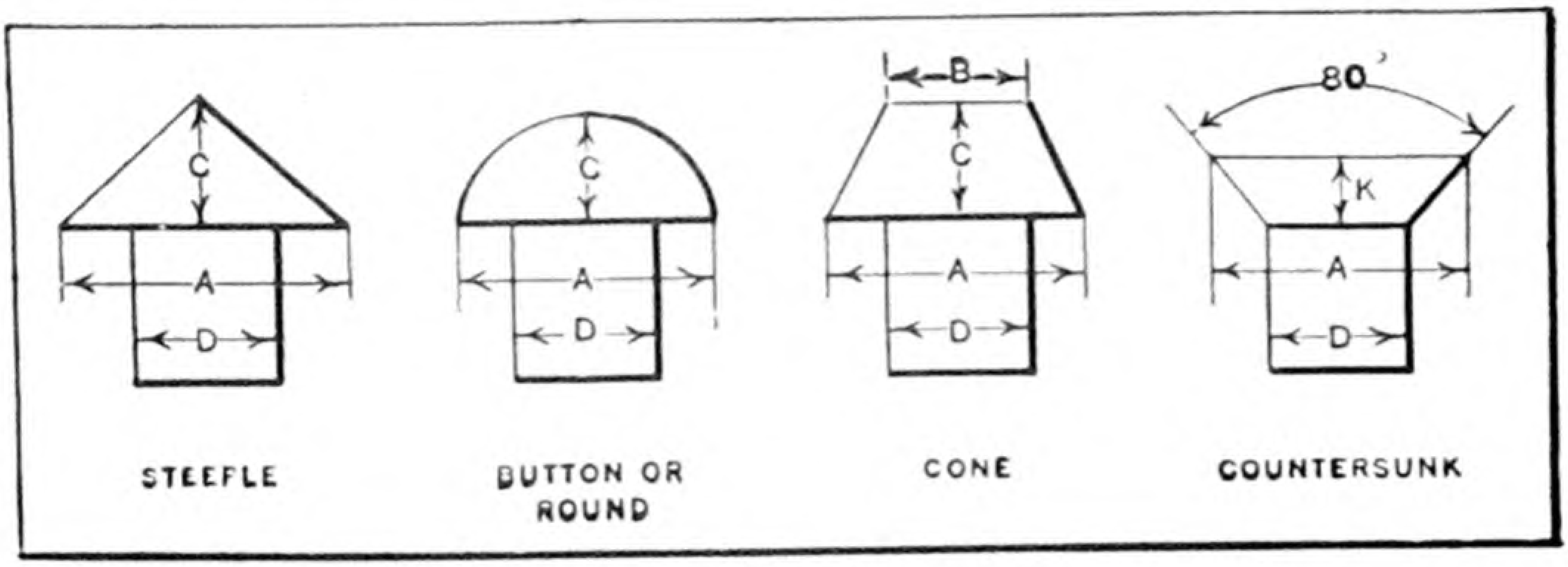


Fig. 2. Rivet Head Dimensions

prominent steel manufacturers, an included angle of 60 degrees is the standard for bridge and structural work.

RIVET DRIVING. In driving cone-head or button-head rivets, they should be "plugged" squarely into the hole, care being taken not to bend over the point of the rivet but to upset it, filling the hole its entire length. A riveting hammer should be powerful enough to form a perfect head without rocking the hammer to work down the edges. The hammer should be started lightly until the rivet has settled into the hole somewhat, to prevent bending to one side. In driving any kind of rivets held or backed up by a dolly-bar or hand-hammer, the riveter must learn to run the hammer slowly until enough head is formed to hold the rivet in the hole, as otherwise the holder-on will have difficulty in keeping the hammer or dolly-bar on the rivet. Getting the rivets into the holes hot and "getting the heads up" is a necessary preliminary to obtaining tight work. For holding the rivet in position, there must be sufficient weight behind it to form a solid anvil against which it may be headed.

RIVETED JOINT CALKING. See Calking.

RIVETED JOINTS CLASSIFIED. When plates to be joined by riveting overlap each other and are held together by one or more rows of rivets, a "lap joint" is formed. In a "butt joint" the plates are in the same plane and are united by a cover plate or butt strap, which is riveted to each plate. A combination lap joint consists of a cover plate inside or outside the lap, and three rows of rivets, the central row passing through the two plates and the cover, and having twice as many rivets as the other two rows. The

term " single riveting " means one row of rivets in a lap joint or one row on each side of a butt joint; " double riveting " means two rows of rivets in a lap joint or two rows on each side of the joint in butt riveting. Joints are also triple and quadruple riveted.

RIVETER, ELECTRIC TYPE. The " electric riveting " process consists in first heating the rivet by electrical means and then subjecting it to sufficient pressure to form the head. The machine used resembles the well-known spot-welder, and in its simplest form is provided with two opposing copper electrodes, the upper of which is movable vertically. After the rivet is in position, the upper electrode is brought down into contact with it. The current induced in the secondary winding of a transformer then flows through the rivet, quickly heating it to the required temperature; then the current is cut off and a greatly increased pressure applied, thus upsetting the rivet and forming the head. The heating of the rivet occurs so rapidly that there is little loss by radiation or conduction. Another type of electric riveter utilizes an electrode for heating and a separate set for forming the head. The operator steps on a foot pedal, the electrode comes down, the rivet heats, operator releases the foot pedal, electrode recedes, the heading set swings over into alignment with rivet and comes down, setting the head. On the setting stroke 80 per cent of the crank motion sends the rivet home and the other 20 per cent presses the parts together while the set dwells on the head. When the setting operation is complete the machine automatically returns to starting position.

RIVETER, HYDRAULIC TYPE. Many riveters, especially of the large sizes used for boiler work, are operated by hydraulic pressure. Some riveters of this general type have a frame which is composed of two sections. The side which carries the cylinder and movable die is known as the *frame*, whereas the opposite side which carries the stationary die is known as the *stake*. The arrangement of the hydraulic cylinder on riveters of different make varies considerably. In general, there is a piston or plunger of comparatively large area which provides the necessary riveting pressure, and a smaller auxiliary plunger for returning the die preparatory to driving another rivet. Many hydraulic riveters are so arranged that two or three pressures may be obtained and, in some cases, there is a larger range of pressures.

Hydraulic Toggle Riveter. — This type of hydraulic riveter is provided with a toggle mechanism through which motion is transmitted from the piston to the riveting plunger. The construction is similar in principle to that employed on many pneumatic riveters, but, instead of using air pressure, the piston is operated by water pressure. The advantage claimed for a riveter of this type as compared with a direct-acting hydraulic riveter is that

a much smaller cylinder is required, because the necessary increase of pressure for riveting is obtained by means of the toggle mechanism; consequently, the riveter occupies less space, is lighter in weight, and requires considerably less power to drive it than one of the direct-acting type.

RIVETER, PNEUMATIC TYPE. One design of pneumatic riveter is so arranged that the piston of the air cylinder imparts motion to the riveting plunger through a combination of levers and toggles which give a gradually increasing pressure until the desired pressure is reached; then, by means of a simple lever movement, approximately the maximum pressure is maintained throughout the remainder of the die travel. This movement of the die under maximum pressure is sufficient to allow for ordinary variations in the length of rivets, size of holes, or thickness of plates after the machine has once been adjusted for a certain riveting operation. The *hydropneumatic compression riveter* is operated both by air and hydraulic pressure, as the name indicates. The air pressure is utilized for moving the plunger down to the rivet and then the pressure is greatly increased by hydraulic means.

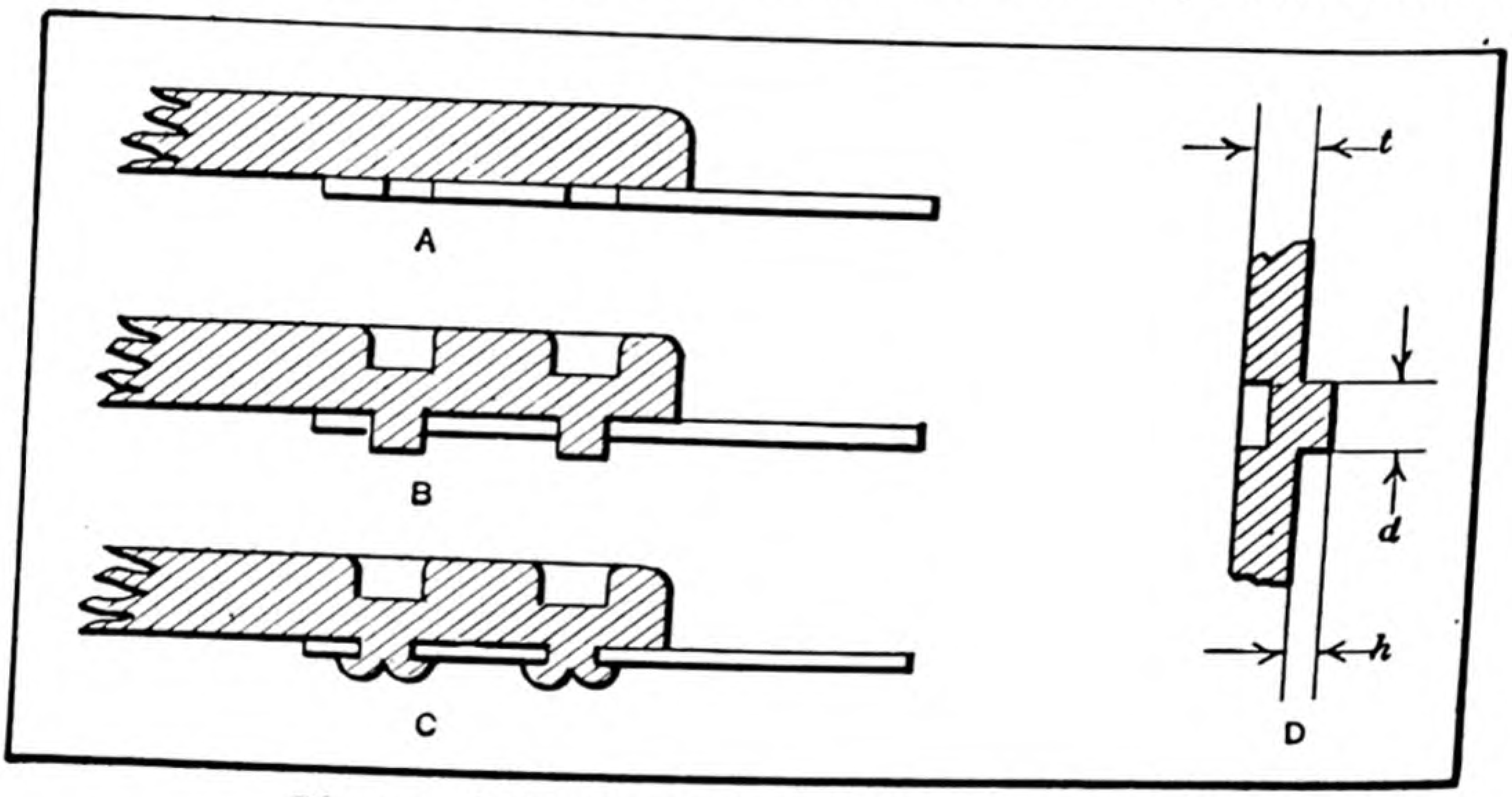
RIVETER, ROTARY VIBRATING TYPE. The rotary vibrating type of riveter may be operated in close corners or other places where there is not sufficient room for the rotating rolls, such as are used on rivet-spinning machines. These machines are also used for general riveting operations. The spindle of a well-known design is vibrated by an eccentric mechanism which transmits motion to the spindle by means of a hickory helve. A rubber ball is interposed between the top of the spindle and the end of the helve to absorb vibration. In addition to the vibrating motion, the spindle is positively rotated by means of a worm and gear, and provision is made for varying the speed of the spindle in order to secure smooth work. It sometimes happens that, with a fixed number of blows per second at a certain rotating speed, the spindle will strike in the same relative position, thereby causing a series of indentations on the rivet heads; hence, provision is made for varying the spindle speed in order to secure smooth work.

RIVETER, TURRET TYPE. This type of riveter is adapted especially for cold riveting automobile chassis frames. The principal feature of this riveter is a rotating turret-head on which four horns or noses are mounted. Any one of these noses may be indexed to bring a stationary rivet die into alignment with the movable die mounted on the plunger or ram. The noses enter the inside of the chassis frame, and must conform in shape to the open space inside of the frame adjacent to and behind the various rivets.

RIVETING MACHINES. The tools and machines designed for upsetting and forming rivet heads include several distinct types. These special tools or machines for riveting may be divided into several general types. First,

they may be classified according to the method of forming the rivet head, which may be either by (1) compression; (2) by a succession of rapid blows; (3) by rapid blows accompanied by rotary motion of the rivet set; (4) by combined compressive and rolling or spinning action; (5) or by the application of pressure to an electrically-heated rivet. "Riveting machines," according to common usage, differ from "riveters" in that the riveting operation with a machine is effected by a succession of blows or by a compressive rotating action, whereas a riveter merely subjects the rivet to compression. These compression riveters may be classified according to the power used for operating the riveting plunger. Thus there are hydraulic, pneumatic, hydropneumatic, steam, and internal-combustion riveters of the compression type.

RIVETS, COLD FORMED. In permanently assembling various light parts, it is often possible to greatly reduce the cost and yet secure sufficient



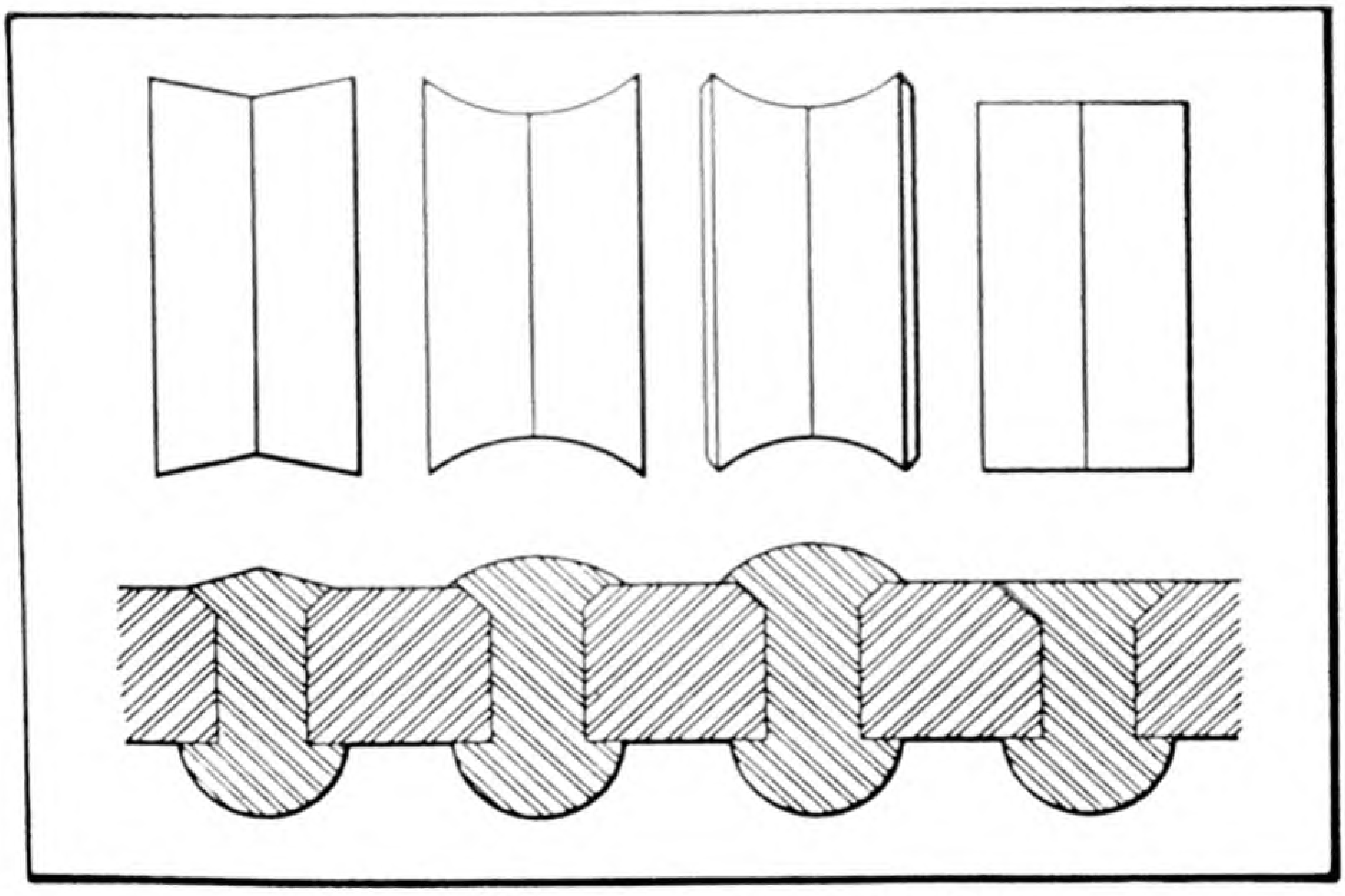
Rivets and Dowels Die-formed on Assembled Part

strength by cold forming in an assembling die, the rivet or rivets as an integral part of one of the assembled sections. Diagrams *A*, *B* and *C* illustrate how a steel spring is cold riveted to the heavier section. Plain round punches descend and form the rivets by forcing metal down through the holes in the spring (see diagram *B*); the metal at the edge is then turned back by the die as at *C*, thus completing the riveting at one stroke of the press. In this particular case, about sixty assemblies per minute are obtained.

Embossed Dowels and Hubs. — When dowel-pins are required to insure the accurate location of parts relative to each other, small projections or bosses may be formed directly on many die-made products, the projection being an integral part of the work and serving as a dowel-pin. Diagram *D*

illustrates how the dowel is formed. The method may be described as a partial punching operation, as a punch penetrates about one-half the stock thickness and forces the boss into a pocket in the die which controls the diameter and compresses the metal, thus forming a stronger projection than would be obtained otherwise. The heighth h of the dowel or boss should not exceed one-half of the dowel diameter d and h should not exceed one-half of the stock thickness t. This is a practical rule which may be applied either to steel or non-ferrous metals, such as brass.

RIVET-SPINNING MACHINES. The rotary rivet-spinning machine forms the rivet heads by means of twin rolls which are carried at the end of a rapidly revolving spindle and are pressed against the rivet head. Four different forms of riveting rolls and the shape of the rivet heads which they



Rolls Used on Rivet-spinning Machines

produce are shown by the diagrams. A pair of these rolls is mounted upon a pin in the roll holder, and as they are pressed against a rivet head each roll revolves independently, thus rolling or spinning a rivet head to a form corresponding to the shape of the rolls. The spindle revolves quite rapidly, the speed for a machine having a maximum capacity of $\frac{3}{8}$ inch being about 1000 R.P.M. In the case of a machine having a maximum capacity of $\frac{3}{16}$ inch, the speed would be increased to about 2000 R.P.M. The spindle is pressed downward by means of a foot-treadle. Special designs of multiple-spindle rivet-spinning machines are sometimes used for duplicate work having a number of rivets which may all be riveted at the same time. One feature of rivet-spinning machines is the absence of noise which is characteristic of hammer-riveting.

RIVETS, PITCH OF. See Pitch of Rivets; also Back Pitch of Riveted Joint.

RIVET STEEL. Rivet steels may be made by either the open-hearth or Bessemer process. The steel should have an ultimate strength of from 48,000 to 58,000 pounds per square inch, and an elastic limit of not less than one-half the ultimate strength. The percentage of elongation should be equivalent to 1,400,000 divided by the ultimate strength. The steel should withstand a bending test in which the material is bent double without fracture on the outside of the bent portion. The maximum allowable phosphorus is 0.10 per cent. For boiler rivet steel, the ultimate strength should be from 45,000 to 55,000 pounds per square inch; elongation, 28 per cent; maximum allowable phosphorus, 0.04 per cent; and maximum sulphur, 0.04 per cent.

Rivet iron is a class of wrought iron adapted to rivets, made entirely from puddled charcoal iron free from any admixture of iron scrap or steel; it has a tensile strength of from 48,000 to 52,000 pounds per square inch.

ROCKWELL HARDNESS TEST. The Rockwell test is a modification of the Brinell. It consists of pressing a hardened steel ball or a diamond cone of 120 degrees angle, into the article to be tested and measuring the depth of impression with a dial micrometer. The size of impression is much smaller than in the Brinell test. The method of applying the Rockwell test is different from the Brinell in that the total depth of depression from the surface is not measured. In making the Rockwell test a minor load of 60 kilograms, regulated by a spring, is first applied to the ball or cone; the micrometer dial is then set at zero, or at a fixed point, and then the major load is applied. Upon releasing the major load the depth of impression caused by the major load only is indicated on the micrometer dial. By using a special reading glass, the diameter of the steel ball depression can be read the same as in the Brinell test. The Rockwell test does not require a standard specimen, and it can be used on much thinner sections than the Brinell.

ROD. A " rod " as the term is applied in rolling mill practice, is generally understood to be a round bar. The United States Government limits wire rods to sizes larger than No. 6 B. W. G. (0.203 inch) in diameter; all smaller sizes are termed *wires*.

In length measure, one rod = 5.5 yards = 16.5 feet = 25 links.

RODDING. In core making, rodding is the process of putting bars or rods in cores in order to strengthen them, so that they may be handled with less risk of being broken. Either loose rods placed in the core or rods held in a cast frame or skeleton may be used.

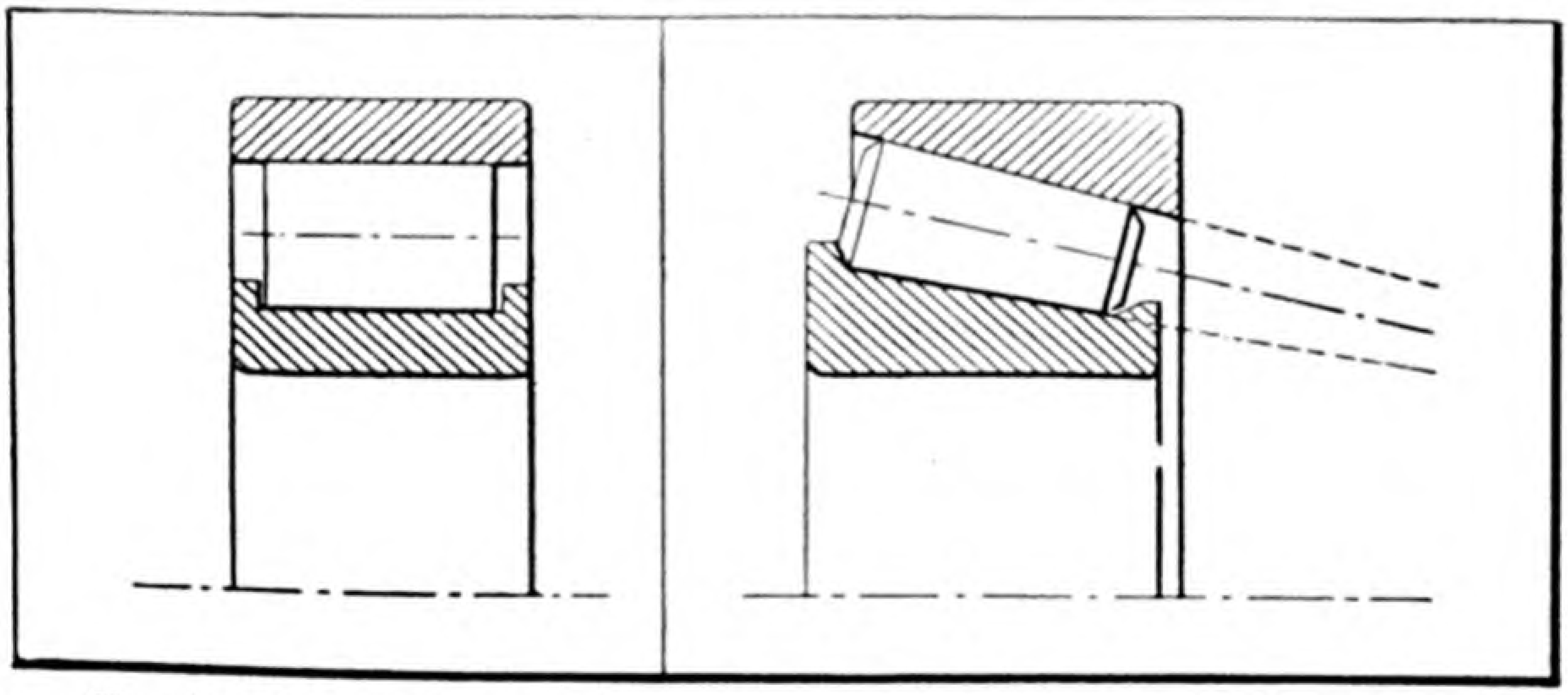
ROD GAGES. See Gages for Rods.

ROEBLING WIRE GAGE. See Steel Wire Gage.

ROLLED JOINT. This form of pipe joint consists of flanges on the pipes, which flanges are clamped between larger flanges by means of bolts. See Van Stone or Rolled Joint.

ROLLER ARBORS. Roller arbors or mandrels are especially adapted for second-operation work. A longitudinal groove is milled in each mandrel, the position of this groove being slightly off center. One or more hardened rollers — according to the style of mandrel — are carried in this groove. By having the groove off center, the roller drops below the circumference of the mandrel at one side of the groove, but, when the mandrel is turned to the left, the roller moves over and binds the work securely. Transverse grooves are machined around the mandrel, and spring collars fit in these grooves so as to hold the rollers in place.

ROLLER BEARING. The load on roller bearings is supported by cylindrical or conical rollers interposed between two races, one race being mounted on the shaft and one other in the bearing proper. There are three principal



Bearing for Radial Load   Bearing for Radial and Thrust Loads

designs of roller bearings. One is for straight radial loads, the lines of contact of the rollers with the races being parallel with the shaft axis, as shown by the left-hand diagram; another design is for combined radial and thrust loads (see right-hand diagram). With this design, the rollers are tapering so that the lines of contact of the rollers with the races, and the axis of the rollers, will intersect, if extended, at the same point on the shaft axis. A third design is intended for thrust or axial loads exclusively. Bearings for radial loads may have solid rollers, or the hollow helically-wound type such as is used in the Hyatt bearing. Although anti-friction bearings have replaced a great many plain or sliding bearings, the trend is toward a much wider application, and evidently will include eventually the heaviest classes

of service since modern anti-friction bearings not only greatly reduce friction losses, but lower maintenance and repair costs.

ROLLER BEARING CAPACITIES. It is impracticable to give a general formula for determining the load capacities of roller or other anti-friction bearings. Different makes of bearings have basic load ratings which represent average or typical conditions, but these basic ratings vary according to the type and make of bearing and the operating conditions under which they have been established. Bearing capacities are influenced by such conditions as mountings, adjustment, lubrication, and protection against dust or other foreign matter. Because of the variations mentioned, bearing capacities should be based upon the manufacturer's recommendation so that the working loads will be in accordance with records of actual performance, which, in many instances, extend over long periods. According to one prominent manufacturer, a basic capacity rating of 100 per cent, suitable for general or typical machinery applications, might have to be reduced 20 or 30 per cent when bearings are subjected to severe shocks, as with the crankshafts of internal combustion engines or when used continuously for exceptionally high speeds.

In determining the capacity of roller bearings, one prominent manufacturer considers the speed; the shaft hardness, when no inner race is used; whether the shaft rotates and the outer race remains stationary, or *vice versa;* and finally, the nature of the service. The basic capacity of bearings decreases as the speed increases. The hardness of the running surfaces also affects capacity, so that shaft hardness is a factor when there is no inner race. If the application is such that the shaft remains stationary and the outer race revolves, the load relationship is not the same as with the revolving shaft, especially for bearings operating directly on the shaft where different shaft hardnesses are used. The nature of the service takes into account such factors as whether it is continuous or intermittent, whether the load is steady or fluctuating, whether the bearing is subjected to shock, overloads and vibrations. The protection from grit or other foreign matter and the attention in regard to lubrication are other service factors.

ROLLER BLIND GUARD. This is an arrangement that is used to a limited extent for protecting the slides of machine tools from chips and grit. It consists of a wide roller mounted at the end of the bed of the machine, having a spring action so that it automatically winds up (similarly to a window shade), a strip of water-and-oil proof material which is attached to the roller at one end and to the moving slide at the other end. As the slide travels, the blind is drawn out or wound up, thus keeping the ways covered at all times. The arrangement has been applied to planers and surface grinding machines.

ROLLER CHAIN. A roller chain differs from a block chain in that bushings and rollers are inserted between the links instead of solid blocks. The rollers are mounted on bushings, and rivets (which pass through the bushings) hold the side links in place. Roller chains of the detachable type are so constructed that the links may be taken apart readily. Roller chains are much stronger than block chains and are used very extensively. They are adapted to higher speeds than block chains and are generally employed when the amount of power to be transmitted is comparatively high.

ROLLER CHAIN NOMENCLATURE. The following nomenclature for roller chains conforms to the practice recommended by the Society of Automotive Engineers: A *roller link* is an inside link consisting of two inside plates, two bushings and two rollers; a *pin link* is an outside link consisting of two pin-link plates assembled with two pins; an *inside plate* is one of the plates forming the tension members of a roller link; a *pin-link plate* is one of the plates forming the tension members of a pin link; a *pin* is a stud articulating within a bushing of an inside link and secured at its ends by the pin-link plates; a *bushing* is a cylindrical bearing in which the pin turns; a *roller* is a ring or thimble which turns over a bushing; *assembled pins* are two pins assembled with one pin-link plate; a *connecting link* is a pin-link with one side plate detachable; a *connecting-link plate* is the detachable pin-link plate belonging to a connecting link; an *offset link* is a link consisting of two offset side plates assembled with a bushing and roller at one end and an offset-link pin at the other; an *offset-link pin* is a pin used in offset links.

ROLLER CHAIN SPEEDS. The maximum speeds for roller chain transmissions have commonly been related to the speed of the chain but scientific observations made by a prominent chain manufacturing company have demonstrated that the destructive action between chains and sprockets is not due to high chain speed (feet per minute) so much as to high sprocket speed (revolutions per minute). Thus the difference in the behavior of two drives is not necessarily due to the difference in chain velocity. The destructive action due to impact between roller and sprocket is proportional to the weight of a chain, link and to the square of the velocity with which the roller strikes the sprocket, and inversely proportional to the projected area of the roller. The velocity of impact between roller and sprocket is proportional to the product of the pitch times the number of revolutions per minute.

If P = pitch; S = maximum number of sprocket revolutions per minute; A = projected area of roller; W = weight per foot of chain, then

$$S = \frac{C}{P}\sqrt{\frac{A}{WP}}$$

where C is a constant to be determined by tests. Experience shows that when C is equal to 2000 this formula gives the maximum sprocket speeds for

satisfactory results, and that, in general, it is desirable to use sprocket speeds not greater than 80 per cent of the maximum speed S.

When one keeps within the proper range with respect to the number of revolutions per minute, there is no known limit to the permissible chain velocities except where centrifugal force becomes great enough to stress the chain beyond its proper working load. By using a sufficiently large number of teeth on the sprockets, roller chains have been driven at velocities as high as 4000 feet per minute, transmitting five times their ordinary rated horsepower at that speed. Such drives, of course, require special attention.

High-speed roller chains are essentially double-roller chains. The weight, pin bearing area, and width of these chains is double that of a single-roller chain of the same pitch, and they are capable of transmitting twice the power at the same speed. The sprocket teeth are cut with the same cutters as are used for single chains of the same pitch and roller diameter. The very satisfactory performance of these double chains, coupled with their low cost, has greatly extended the field of usefulness of the roller chain, and except where extreme quietness of action is required, they will fill all ordinary requirements for either low or high speeds.

ROLLER CHAIN SPROCKET DESIGN. See Sprocket.

ROLLER FOLLOWER. This is the part of a cam-operated device which is directly actuated by the cam. A roller at one end of the follower or driven member presses against the cam surface in order to reduce the frictional resistance.

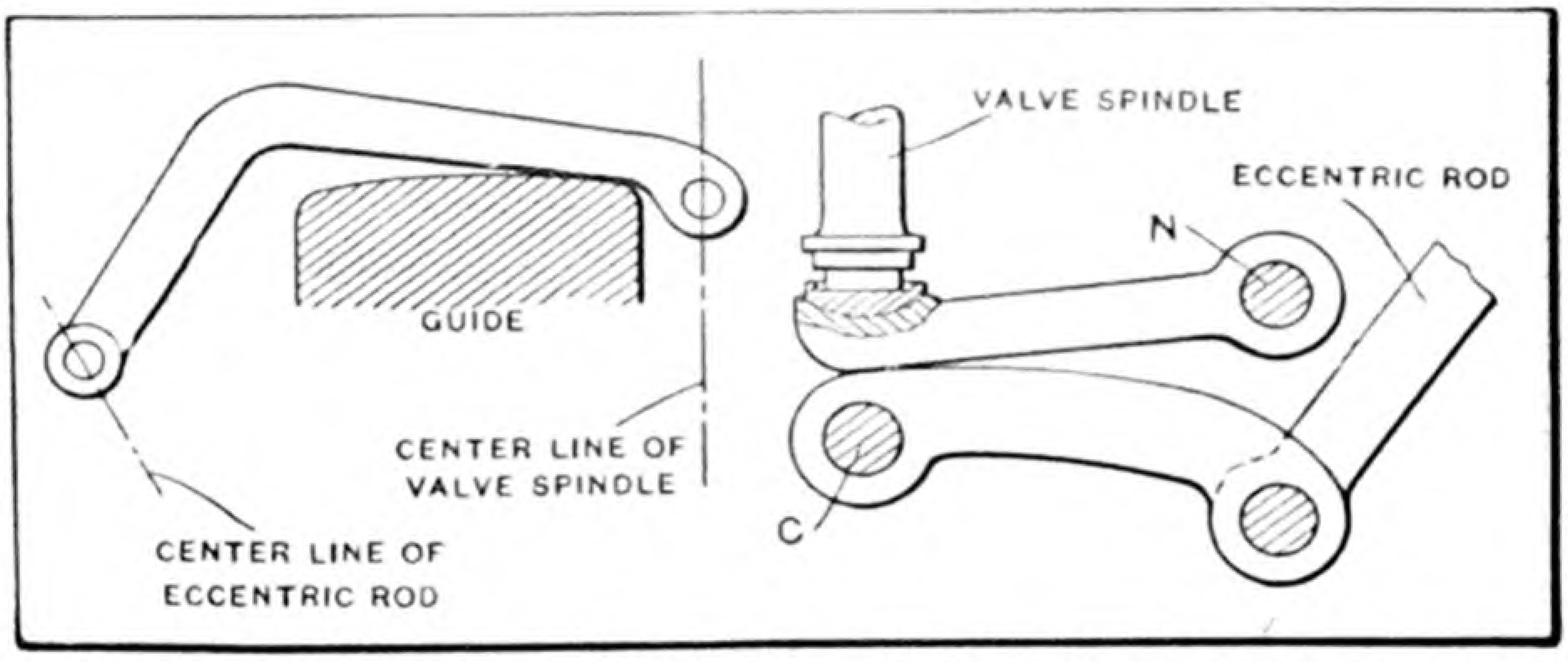
ROLLER GRATE. This is a furnace grate of the shaking-grate type, the name of which is derived from the fact that the grate bars are supported in roller bearings.

ROLL FEED MECHANISM. When a power press is used for producing plain blanks or shallow drawn or formed parts from strip stock, a roll feed mechanism is commonly used. The stock passes between two rolls mounted one above the other, which feed it under the dies a predetermined amount for each stroke of the press. These rolls are geared together and rotated by a ratchet-and-pawl mechanism. The ratchet wheel is mounted at the end of one roll and is operated by a rod connecting with a crank attached to the end of the crankshaft. By varying the position of the crankpin, the feeding movement of the stock can be changed as may be required. These feeding rolls may be located so as to feed the stock laterally or between the sides of the press frame; that is, the feeding mechanism may be located at either side of the press table or at the front or rear. The feed-rolls of presses are commonly provided with an automatic release. This release is so arranged that the grip of the rolls upon the stock is momentarily released at every

stroke as the punch descends, and is a desirable feature when pilots are used in the ends of the punches, in order that the stock will be free to move slightly in case the pilots are not in exact alignment with the pierced locating holes. See also Power Press Roll Feeds.

ROLLING FRICTION. Rolling friction is the force that retards the motion of a body rolling over a surface. See Friction.

ROLLING LEVERS. So-called " rolling levers " may be classified as a special form of cams. Rolling levers are employed to actuate the valves of large gas engines as well as the poppet-type valves of steam engines. These levers may be divided into two classes — the single-lever type (see



Rolling Lever of the Single-lever Type

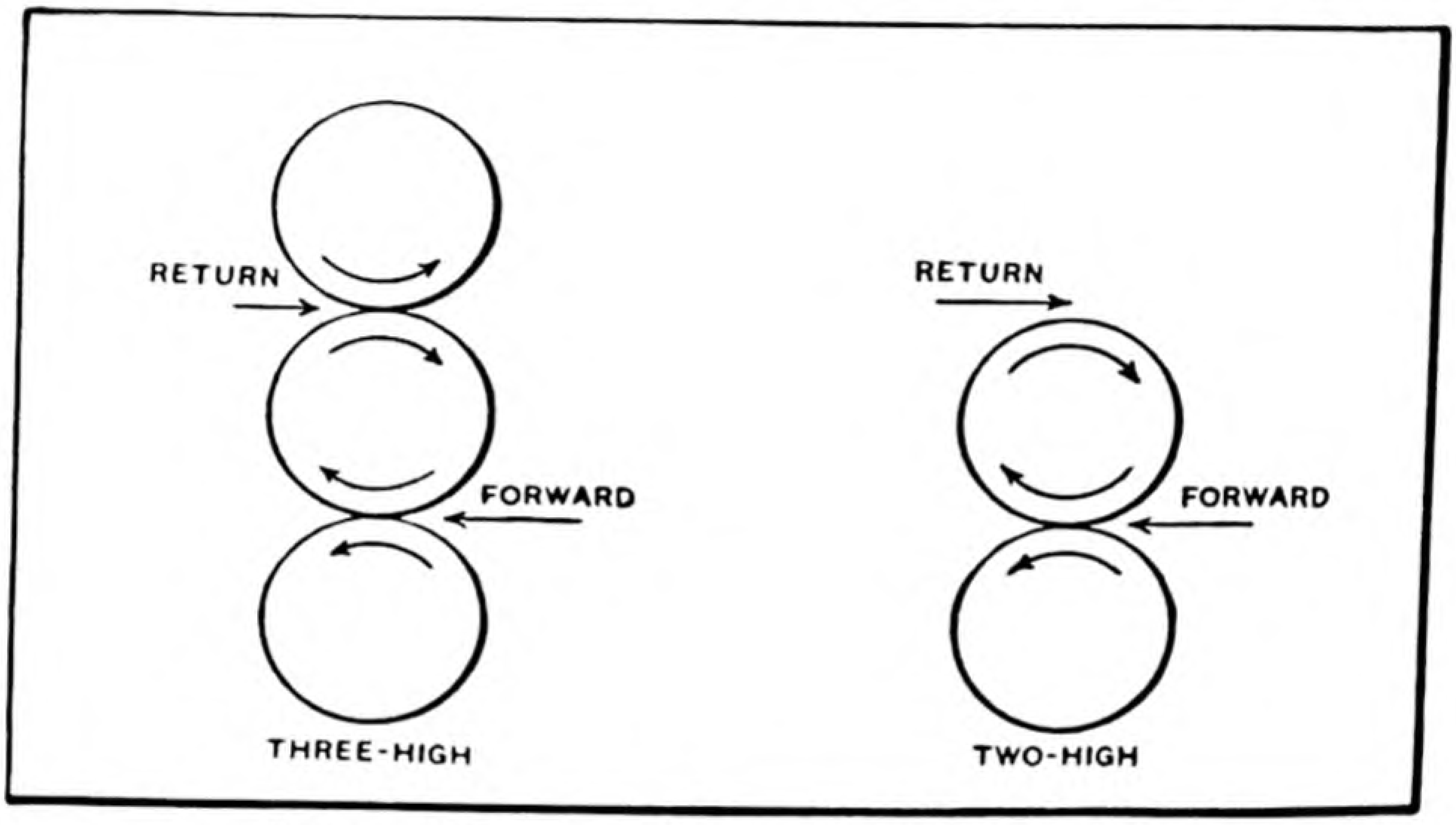
Rolling Lever of the Double-lever Type

illustration) and the double-lever type. In the first case the lever rolls on a fixed guide, and thus has a continuously moving fulcrum, which travels from one end of the guide to the other. In the second case the levers are fulcrumed at fixed points, as at *C* and *N*, and roll upon each other. The levers should have a pure rolling motion in order to insure a minimum of wear. The valves should be opened quickly and should close with a constantly decreasing velocity, so as to seat quietly and without shock.

ROLLING MILLS. The term " rolling mill " is applied to machines used for rolling bars, rails, sheets, etc., and also to the plant in which the rolling mill operations are conducted. Considering the machines, rolling mills are used for producing steel or wrought-iron bars of uniform cross-section and flat sheets or plates, by passing a short heavy piece of stock between rolls which gradually reduce it to the required form. The rolls are either cast-iron or steel cylinders which, for rolling bars, rails, etc., have a series of grooves for gradually reducing a heated ingot, billet, or bloom to the cross-sectional shape required. For rolling flat sheets or plates, plain cylindrical rolls are employed. After the stock is caught between the rolls, it is drawn through by friction, and the reduction in thickness resulting from each pass

causes a corresponding increase in length. The change in cross-sectional shape of a bar or the reduction in thickness of a flat plate due to one passage through the rolls are comparatively small, so that several passes are required.

Types of Rolling Mills. — Rolling mills are "two-high" or "three-high," depending upon whether two or three rolls are mounted one over the other; these mills are shown diagrammatically by the accompanying illustration. In the *two-high* mill, the metal is acted upon on its forward pass, but not on its return; in the *three-high* type, the metal is acted upon on both passes. The rolls vary in size from 6 inches in diameter, for those used in making merchant bar, to 50 inches in diameter, for those used in making armor plate.



Action of Three- and Two-high Rolling Mills

To avoid the idle pass, two-high rolls are often made reversing. In that case, as soon as the bar is passed through the rolls, the engine reverses the direction of the rolls and the bar is passed through in the opposite direction. In the two-high non-reversing mill, all impurities are worked toward one end of the bar, because the metal passes through in the same direction each time, but in the three-high and the reversing two-high mills, the impurities are worked toward the middle of the bar, as the bar is rolled from each end.

Blooming mills are used to reduce ingots to blooms, billets, or slabs. These mills are usually of the two-high reversing type, although the three-high non-reversing type is employed.

Billet mills are used to reduce the blooms to a section $1\frac{1}{2}$ inch square or larger so that these billets may be used for bars and rods. These mills are three-high and the rolls are from 24 to 32 inches in diameter.

Sheet-bar mills reduce slabs and blooms to sheet bars so that they may be used in sheet and tin mills. These mills are three-high and the rolls are from 24 to 32 inches in diameter.

Beam mills are used for heavy beams and channels 12 inches and over.

The mills are three-high and the rolls are from 28 to 36 inches in diameter. Smaller beams and channels, and other structural shapes, are made in shape mills, in which the rolls are from 20 to 26 inches in diameter.

Merchant-bar mills have rolls from 16 to 20 inches in diameter, although the smaller bars are made in mills having rolls from 8 to 16 inches in diameter, but have generally a larger size roughing stand.

Universal mills have vertical and horizontal rolls, so that all four sides are rolled simultaneously, and are adapted for rolling square-edged plates and various wide-flanged shapes.

ROLLING MILL, UNIVERSAL. See Universal Rolling Mill.

ROLLING SCREW THREADS. See Thread Rolling.

RONAY PROCESS. This is a method for briquetting metal chips without the use of a binding material. The material to be briquetted is subjected to a heavy hydraulic pressure, approximating 35,000 pounds per square inch. Cast iron, steel, brass, bronze, aluminum, and copper chips, borings, and filings, as well as graphite, ore, flue dust, etc., may be briquetted in this way.

RÖNTGEN RAYS. See X-ray.

ROOT. In mathematics, a root of a given quantity, is the quantity which, when repeated as a factor a number of times equal to the index of the root, will give as a product a given number. For example, $\sqrt[4]{81} = 3$, because 3 repeated as a factor 4 times gives 81 as the product.

ROOT DIAMETER OF SCREW THREAD. The root diameter is the diameter of a screw across the bottom or root of the thread, measured at right angles to the axis of the screw. The *root* is the bottom of the groove which forms a thread, whether the thread be external or internal. According to the American Standard definitions for screw threads, the terms " root diameter " and " core diameter " have been replaced by the term " minor diameter," which also replaces " inside diameter " as applied to the thread of a nut. The minor diameter is the smallest diameter of an external or internal screw thread.

ROOT-MEAN-SQUARE (R.M.S.). The square root of the mean of the squares of the instantaneous values for one complete cycle of an alternating current is the root-mean-square or effective value and it is usually abbreviated r.m.s. Unless otherwise specified, the numerical value of an alternating current refers to its r.m.s. value. The r.m.s. value of a sinusoidal wave is equal to its maximum, or crest value, divided by $\sqrt{2}$. The word " virtual " is sometimes used in place of r.m.s., particularly in Great Britain.

ROPE. See Arc Light Rope; Cable-laid Rope; Haulage Rope; Hemp Rope; Hoisting Rope; Manila Rope Strength; Wire Rope.

ROPE-LAY CABLE. In electricity, this is a single-conductor cable composed of a central core which is surrounded by one or more layers of spirally- or helically-laid groups of wires. A rope-lay cable differs from a concentric-lay cable in that in the former the main strands are stranded.

ROPE, NON-SPINNING. Non-spinning rope is a special type of wire rope made from eighteen strands of seven wires each. The object of so-called " non-spinning " hoisting rope is to prevent a free load suspended at the end of a single line of rope from rotating. The spinning of a rope endangers the life of workmen, and the constant attention required to guide the load is difficult and expensive. Non-spinning hoisting rope is constructed by first placing six strands of seven wires each (Lang's lay) around a hemp core. These six strands are then covered with an outer layer composed of twelve strands with seven wires to the strand laid in " regular " lay — that is, the wires in the strands are twisted to the left, but the strands themselves are twisted to the right or wound around the wire rope in the direction of a right-hand screw thread. Ropes of this type are made from various materials, according to the strength required for the service for which they are intended.

ROPE SPLICING. When two pieces of rope are joined by unlaying the strands and weaving or intertwining the strands of one end with those of the other, the operation is known as *splicing*.

Short Splice. — The first step in making a short splice is to unlay or untwist the strands at the end of each rope. After the ropes are placed together, as shown at *A* (see Fig. 1) the strands on one side, as shown at *d*, *e*, and *f*, are either held together by the left hand or are fastened together with twine, in case the rope is too large to be held by the hand. The splicing operation is started by taking one of the strands as at *a*, and passing it across or over the adjacent strand *d* and then under the next strand *e*, after having made an opening beneath strand *e*. The strands *b* and *c* are next treated in the same manner, first one and then the other being passed over its adjoining strand and then under the next successive one. These same operations are then repeated for the strands *d*, *e* and *f* of the other rope. The splice will now appear as shown at *B*. In order to make it stronger and more secure, the projecting strands of each rope are again passed diagonally over the adjoining strands and under the next successive ones. The splice should then be subjected to a strong pull, in order to tighten the strands and make them more compact. The projecting ends of the strands should then be cut off, thus completing the splice as shown at *C*. For making the openings beneath the strands on the rope, what is known as a *marlin spike* is

generally used. This is merely a tapering, pointed pin made of wood or iron.

Long Splice. — When a rope has to pass through pulley blocks, or in case any increase in the size of the rope would be objectionable, the short splice

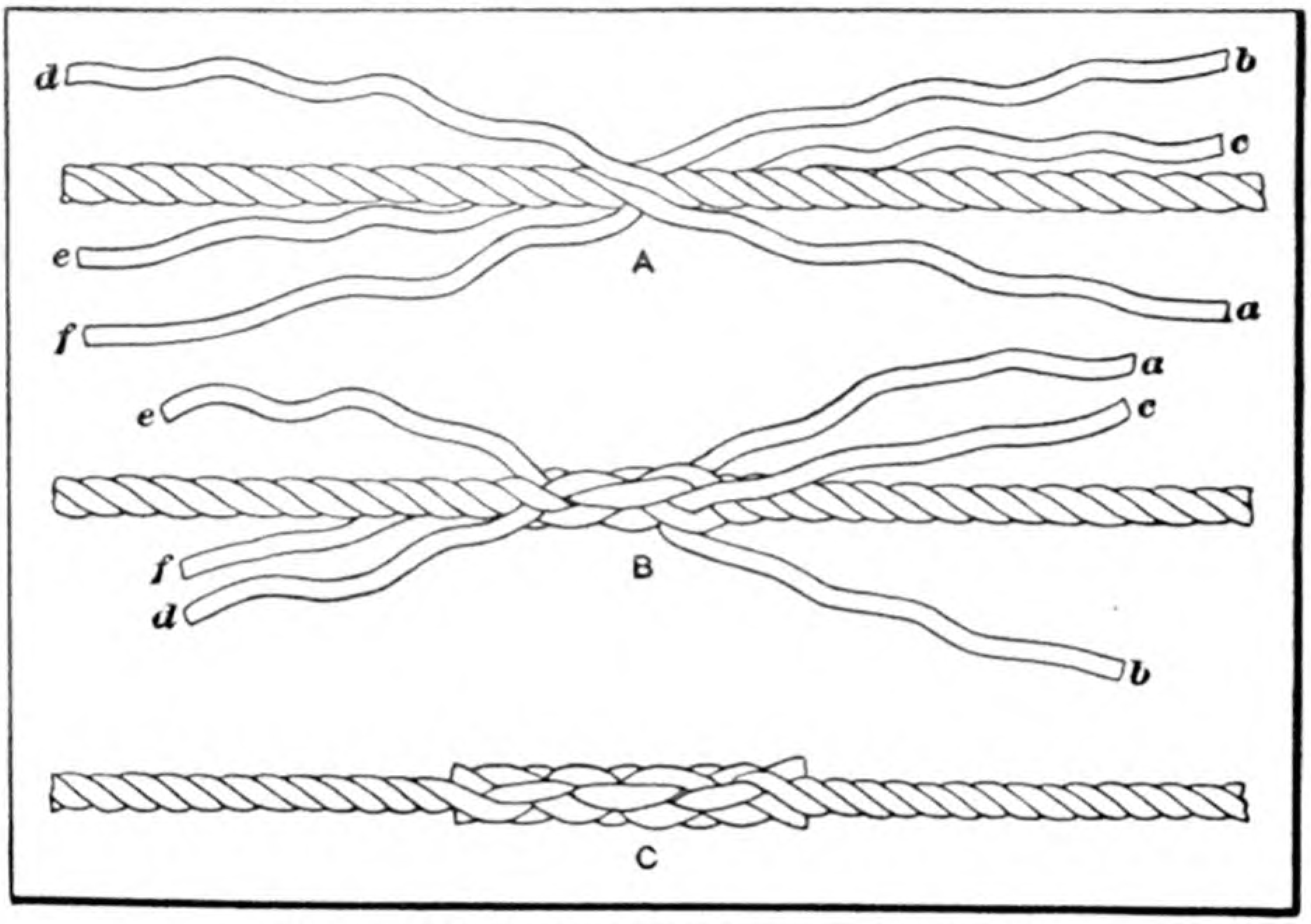


Fig. 1. Method of Making a Short Splice

is not suitable and the long splice should be employed. The diameter of a long splice is the same as that of the rope and, if the work is done carefully,

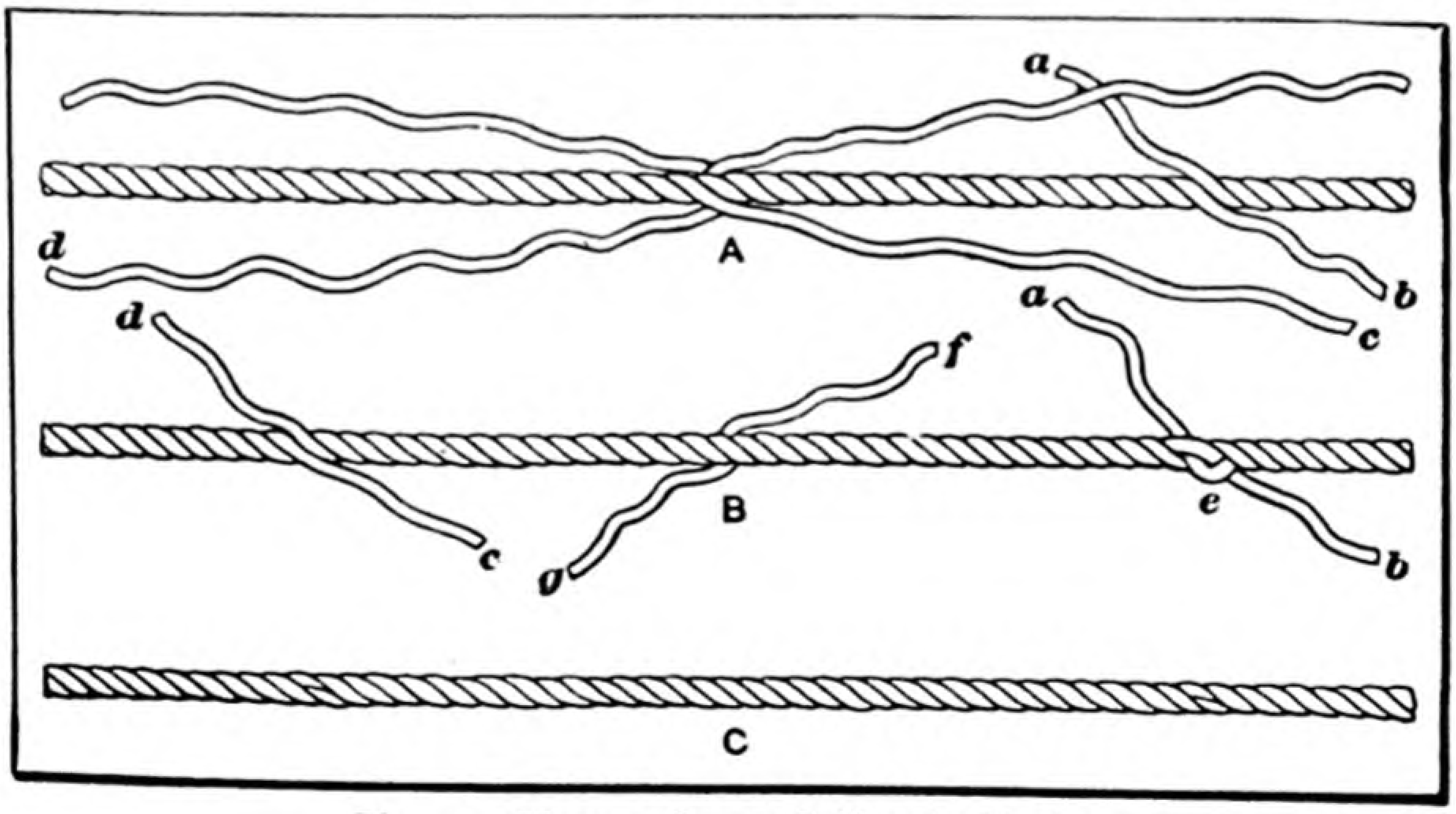


Fig. 2. How a Long Splice is Made

the place where the ends are joined can scarcely be distinguished from the rest of the rope. The ends of each rope are first unlaid or untwisted the same as when making a short splice, but for a distance about three times as long.

These ends are then placed together so that each strand lies between two strands of the other rope, the same as for a short splice. One of the strands is next unlaid and then a strand from the other rope is curled around into the groove thus made, as indicated at *A* (see Fig. 2), strand *a* having been unlaid and strand *b* from the other rope end, put into its place. Care should be taken to twist strand *b* so that it will lie in its natural position into the groove previously occupied by strand *a*, as the neatness of the splice will depend partly upon the care with which this part of the work is done. This operation is then repeated in connection with strands *c* and *d*, strand *c* being unlaid and strand *d* twisted around to occupy the groove thus made. The splice will now be as shown at *B*, and the next step is that of disposing of the protruding ends of the strands. After these strands have been cut to about the length shown at *B*, two of the strands, as at *a* and *b*, are first reduced in size by removing about one-third of the fiber; these ends are then tied by an overhand knot as shown at *e*. After tightening this knot, the protruding ends may be disposed of the same as when making a short splice, or by passing them over the adjoining strand and through the rope, under the next one. By gradually removing the fiber each time the end is passed across an adjoining strand, the enlargement of the rope at this point may be made very slight and scarcely noticeable. The strands *f* and *g* which remain in their original positions in the center of the splice, and also the strands *c* and *d* are disposed of in a similar manner, thus completing the splice as shown at *C*. See Eye-splice.

ROPE, STEEL-CLAD HOISTING. This is a wire rope which has each strand covered with flat steel strips wound spirally around them in order to provide additional wearing surface. These ropes are used in cases where the rope is subjected to extreme wear, and give additional wearing surface without sacrificing the flexibility. The life of the wire rope exposed to great wear may be increased from 50 to 100 per cent by this construction.

ROPE TRANSMISSION. There are two systems of rope transmission which are known as the American or continuous system and the English or multiple system. In the *American or continuous system* of rope driving, one long rope is wound around the driving and driven pulleys several times or until all of the pulley grooves have been filled; the rope is then conducted from the last groove of the driven to the opposite groove of the driving pulley by means of an idler, which is held at the required angle. The *English or multiple system* differs from the American system in that a number of parallel ropes, one in each groove in the pulleys, are used instead of a single rope that is wound around the pulleys continuously. The required tension is obtained by the weights of the ropes, no tension carriage being employed; hence, in the multiple system, the driving and driven sheaves should be located far enough apart to obtain the required tension.

Ropes. — Cotton ropes are generally considered better than Manila ropes for power transmission because they will transit more power and will wear longer. The initial cost, however, is greater. Cotton ropes are used chiefly in England, and Manila ropes in the United States. The life of driving ropes depends upon their size and the conditions under which they work. The most economical diameters for cotton ropes range from $1\frac{1}{2}$ to $1\frac{3}{4}$ inches, the larger size being commonly used for transmitting considerable power. Regarding the relative merits of the three- and four-strand ropes, the former is superior in that it will transmit the same power with a fewer number of ropes. The four-strand rope, however, has the advantage of stretching less, and there is a larger surface in contact with the pulley grooves; it is also capable of a stronger splice. A well-made four-strand rope is, moreover, nearly as strong as a three-strand rope, but it requires more skill to splice it. A three-strand rope rotates once for every nine feet of travel; a four-strand rope rotates once for every twelve feet of travel; and a six-strand rope rotates once for every twenty-four feet of travel.

Rope Speeds. — The speed of driving ropes usually varies from 2000 to 5000 feet per minute. The most economical speed is between 4500 and 5000 feet per minute. If the speed is too low, the ropes are likely to slip, and if it is too high, the action due to centrifugal force affects the efficiency. As the ropes operate in V-shaped grooves, the loss due to centrifugal force is less than with belt drives; hence, ropes are adapted to higher velocities.

Wire Rope Transmission. — The application of wire rope for the purpose of transmitting power was first made in 1850, in Switzerland. With this system of transmission, an endless wire rope is employed which runs over large sheaves, the grooves of which are usually filled with rubber or wood. Ordinarily, the sheaves are of cast iron and are made as light as possible. In addition to the rubber and wood fillers, various other materials have been used for filling the grooves, such as tarred oakum, jute yarn, and leather. With rubber and leather fillings, considerably more power can be transmitted than when using wood-filled sheaves. As a general rule, this system of transmission should not be used for shorter center-to-center distances than 50 feet, and it may be employed without supporting idler sheaves, for distances up to 300 feet. For greater distances, guide sheaves should be used at points 300 feet apart or less. Double-groove sheaves are also used in some cases; these are spaced 300 feet apart and serve to divide the transmission system or rope into a number of independent sections.

ROSE CHUCKING REAMER. This is an end-cutting reamer used for enlarging cored or drilled holes. The cylindrical part of the reamer has no cutting edges, but merely grooves cut for the full length of the reamer body, providing a way for the chips to escape and a channel for lubricant to reach the cutting edges. There is no relief on the cylindrical surface of the body

part, but it is slightly back-tapered so that the diameter at the point with the beveled cutting edges is slightly larger than the diameter further back. The back-taper should not exceed 0.001 inch per inch. This form of reamer usually produces holes slightly larger than its size and is, therefore, always made from 0.005 to 0.010 inch smaller than its nominal size, so that it may be followed by a fluted reamer for finishing.

ROSIN OIL. This oil is obtained from common rosin by distillation, and is not suitable for the lubrication of machinery, but nevertheless it has been used to adulterate mineral and other lubricating oils.

ROTARY BLOWER. A rotary blower, also known as a "positive blower," is a blower consisting of a casing in which two moving elements revolve in opposite directions, one or both of which are called *impellers*. The impellers are of double-lobe cycloidal form, so that they engage with each other and force air between them, as they rotate, from the inlet to the outlet. Rotary blowers are positive in their action and are used for furnishing blast for cupolas, gas and oil burners, furnaces, ash conveyors, pneumatic tube service, etc.

ROTARY CARBURIZING. See Carburizing by Rotary Method.

ROTARY CONVERTER. This is an electrical machine used for converting alternating current into direct current. See Synchronous Converter.

ROTARY ENGINE. The rotary type of steam engine differs from the reciprocating type in that the steam pressure is applied to some form of piston, or series of pistons, which is connected directly to the main shaft and revolves about the axis of the cylinder. Many attempts have been made to design a rotary engine that could compete with reciprocating engines, but, up to the present time, the rotary type has not proved successful. The chief theoretical advantage of the rotary principle is that the power is utilized directly to produce rotary motion without any intervening mechanism, thus eliminating a reciprocating piston and cross-head, and an oscillating connecting-rod, with their mass, inertia and vibration. The object of inventors has been to design a rotary engine that would not only possess the advantage of directness in the application of power, but, in addition, compactness and simplicity of construction. The principal disadvantages of most designs have been leakage, internal resistance or friction, and failure to use the steam expansively, all of which result in excessive steam consumption. Rotary engine designs differ considerably as to the form of the parts corresponding to the piston, and also in regard to the kind of abutment or diaphragm used to separate the exhaust and inlet sides and compel continuous motion of the piston from the point of admission to the point of release or exhaust. The importance of the rotary type has become much

less since the development of the steam turbine. The chief distinction between the rotary engine and the turbine is that the former is operated by pressure action, whereas, in the turbine, the kinetic energy of a mass of steam moving at high velocity imparts motion to the rotor or rotating member.

ROTARY FILES. Files of the rotary type are made in either cylindrical, conical, spherical, concave, or special shapes for finishing the edges or surfaces of punches, dies, metal patterns, and various other classes of work. The file may be rotated by inserting it in a drilling machine spindle, as for finishing the edges of punches or dies, or by using a flexible shaft drive, as when the position of the file must be varied by hand control.

ROTARY FILING MACHINE. A machine provided with one or two rotating disks against or between which the object to be filed is placed is used specifically in the manufacture of steel balls for removing the fin from forged ball blanks before grinding. This process is generally known as flashing, and the machines are sometimes called " flashers," or rotary files.

ROTARY MILLING MACHINE. Castings or forgings which are so shaped as to be readily clamped or released from a fixture are sometimes milled by a continuous circular milling operation. This may be done by the use of a circular attachment on a vertical milling machine, or on a special machine equipped with a circular revolving table. The continuous rotary milling machine is designed along the lines of an ordinary vertical milling machine, but is intended for milling large quantities of duplicate parts. The castings or forgings to be milled are held in a fixture near the edge of the table and, as the latter revolves, one piece after another passes beneath the revolving cutter and is milled or faced. As the finished parts come around to the front of the machine, they are removed by the operator and replaced by rough pieces without stopping the machine, so that the milling operation is practically continuous. A fixture for continuous circular milling must be designed so that the work can be removed quickly and without stopping the rotation of the table.

The increased production that has been effected in many cases by substituting continuous rotary milling for some other method is due to reducing the non-productive time of the machine by avoiding the necessity of stopping to set up work and then restarting the machine; by avoiding the need of returning the table to the starting point after each traverse; and by overcoming the necessity of having the machine idle while the operator is setting up work, or the operator idle while the machine is running.

ROTARY PLANERS. The rotary planer or " end milling machine," as it is sometimes called, is especially adapted to the planing or slab milling of heavy castings or forgings. The distinguishing feature of a rotary planer

is the large circular cutter head which carries inserted tools or cutters which successively cut away the metal as the cutter head revolves. The slide which carries the cutter head and driving mechanism of some rotary planers, is mounted on a horizontal bed and automatically feeds along this bed, when the machine is in operation. The part to be planed or milled is attached to a stationary work-table. Other rotary planers have a cutter head which remains stationary and a work-table which is given an automatic feeding movement. This type may have either a fixed cutter head or one that can be adjusted vertically. There are also several other variations in the design of rotary planers. Some machines are mounted upon a circular sub-base so that the bed carrying the cutter-slide can be swiveled, for planing the ends of long heavy parts at an angle. For finishing both ends or sides of the work at the same time, *duplex rotary planers* are used. This form consists of two planers mounted on one bed. One cutter head may be attached to a fixed base and the other to a swiveling base, or both heads may have fixed bases. The size or rated capacity of a rotary planer is equivalent to the diameter of the circle described by the tools in the cutter head.

ROTARY PUMPS. Rotary pumps are designed to operate with a continuous rotary motion instead of a reciprocating movement. In these pumps, the liquid is trapped between the revolving blades or wings of an impeller and the outer pump casing, and is forced around from the suction side to the discharge side. Pumps of this class may have either two or more lobes on each impeller. Rotary pumps, when properly designed, are simple and reliable, but usually the percentage of slip is comparatively high and leakage is liable to become excessive as the result of wear, especially when pumping against considerable pressure. Pumps of this type are used principally for thick or heavy liquids, or for liquids containing pulp, malt, or similar materials. They have also been applied to many machine tools for supplying oil to the cutting tools.

ROTARY SHEARS. Rotary or circular shears are so named because the shear blades are in the form of disks. These disks are mounted on parallel shafts which rotate in unison. Shears of this kind are used for cutting curved sheets or for circular work. For the latter, the sheet or plate is held at the center of the disk to be cut, by a clamp which allows the sheet to revolve when the shears are cutting.

ROTARY SWITCHES. Under this classification may be grouped a number of different kinds of switches used for various purposes in connection with power station switchboards. Among these are rheostat switches, voltmeter switches, and instrument reversing and transfer switches.

ROTOR. When an important member of a machine revolves within a stationary casing or outer member, the rotating part is often called a rotor.

For example, in a centrifugal pump, the rotor is a rotating element provided with vanes, which draws in air or liquid at the center and expels it at a high velocity at the periphery. The rotor of a steam turbine revolves within its casing as the steam impinges alternately against the rotor blades and the stationary casing blades. Various other rotating parts are known as rotors.

ROUND CHISEL. This chisel is intended for the cutting of oil grooves or other grooves having a round bottom. The point of the chisel is round and the end surface is ground off at an angle to produce a cutting edge.

ROUND FILE. Round files (also called " rat-tail ") are made both in the taper and blunt forms, and the cut is mostly bastard. Round files are used either for enlarging round holes or shaping internal surfaces for which quadrangular sections would be unsuitable. The blunt shape is ordinarily used for the heavier classes of work. Both square and round files are made in " slim " forms, which are of regular length but of smaller cross-section.

ROUTING. Routing is a name given the operation of milling when the feeding movements of the work are controlled by hand, in order to follow an irregular outline, as when roughing out the impressions in drop-forging dies, etc.

ROYALTIES ON PATENTS. The customary royalty paid by manufacturers for the privilege of manufacturing and marketing patented mechanical devices may be either a certain percentage of the selling price or a certain fixed amount for each article manufactured, but the amount varies in almost every case because of the endless variety of conditions that affect royalties. It is not feasible to give general figures, as a royalty which is too high in one case may be entirely too low in another. For instance, when the manufacturer must invest in new equipment, and when the cost of selling a product is likely to be high, it is apparent that the manufacturer should have a larger royalty than would be required if the risk assumed were less. Because of these variable factors, 5 per cent royalty might be fair to both patentee and manufacturer under given conditions, and too low under other conditions. In other words, it is not feasible to establish the royalty by considering what someone else has done, but rather to establish it on a business basis, considering the facts covering the particular case under consideration.

ROYALTY CONTRACTS. Royalty contracts are usually made on the basis of the inventor receiving a certain per cent of the retail selling price, or in some cases a percentage of the price obtained by the manufacturer. A much better arrangement is an agreed amount per article. In some cases the inventor agrees to take a certain proportion of the profits. This is usually a very poor arrangement, as the inventor is in effect and usually in fact a partner, and may become liable for the debts of the business; and in

any case he has to find out what the profits are, which is often a matter for much argument and contention. The manufacturer should agree to keep an accurate account of the number of articles sold and to report and remit at stated times. He should also agree to allow the inventor free access to his books during business hours, and should agree to swear to the correctness of the books and the reports if required to do so by the inventor. Sometimes it is possible to give the articles consecutive serial numbers, which makes the accounting easier, and sometimes the inventor furnishes name-plates or labels at so much apiece, which the licensee affixes to the article. The main considerations are to see that the contract is definite as to what is to be done, and the exact time that it is to be done, and to provide that if it is not done, all rights shall revert to the inventor.

RUBBER. Rubber is obtained from certain trees and bushes found in the tropical regions of America, Africa, and Asia. Commercial rubber contains a number of foreign substances which can be removed by mechanical washing and drying. The washed and dried rubber is then treated according to the purpose for which it is to be used. In engineering, one of the most common uses of rubber is for electrical insulation. When rubber is to be used for this purpose, the washed and dried product is passed between rollers and pressed into sheets, after which it is cut up into pieces, again passed through the rollers, and compounded with various mineral substances, hydrocarbons, and sulphur, this process being known as "compounding." From 60 to 70 per cent of mineral substances may be added to the rubber gum before the essential qualities of the rubber cease to predominate. Commercial insulating rubber, for example, generally contains only about 30 per cent of rubber, while it may contain from 30 to 65 per cent of zinc oxide, up to 30 per cent of whiting, from 1 to 12 per cent of litharge, from 2 to 4 per cent of paraffin, and from 2 to 4 per cent of sulphur. A number of other substances are also present in small quantities. "Hard rubber" is defined as a rubber compound hard enough to be machined and polished. Hard rubber is vulcanized — that is, the soft rubber has been treated with sulphur so as to change it into a harder product than the original rubber.

RUBBER BELTS. Rubber belts generally are made up of 28-, 32-, and 36-ounce duck, and their ultimate tensile strength varies from 900 to 1500 pounds per square inch according to the fabric used. The higher frictional resistance of rubber belting, as compared with leather, is offset by the heavier weight (0.0478 pound per cubic inch, as against 0.038 pound per cubic inch for leather belts) which results in centrifugal force having a greater effect. Owing to the nature of a rubber belt (which is made up of plies) it is desirable to avoid extremely small pulleys whenever possible.

Rubber belts are made either with a special friction surface or with a

rubber cover and in almost any width. The number of plies ranges from two to fourteen. The various brands vary slightly in tensile strength and weight. The average weight of rubber belting per square foot and ply is: 0.3699 pound for 28-ounce duck; 0.3893 pound for 32-ounce duck; and 0.4923 pound for 36-ounce duck. To find the weight per lineal foot of a rubber belt, multiply the weight per square foot and ply by the number of plies and the width of the belt, in inches, and divide by 12.

RUBBER BELT VELOCITIES. Owing to the greater effect of centrifugal force, the velocity of a rubber belt varies according to the cotton fabric used. The following are the most effective speeds for different cotton fabrics: 3000 feet per minute for belts made of 28-ounce duck; 2700 feet per minute for belts made of 32-ounce duck; and 2400 feet per minute for belts made of 36-ounce duck. These velocities cannot be exceeded without decreasing the effective pull. The limiting velocities at which the effective pull of a rubber belt equals the working stress minus the centrifugal force are as follows: 3800 feet per minute for belts made of 28-ounce duck; 3500 feet per minute for belts made of 32-ounce duck; and 3200 feet per minute for belts made of 36-ounce duck. At these velocities the coefficient of friction reaches its highest value, and nothing can be gained by further increase, as the power-transmitting capacity will be reduced rapidly.

RUBBER BOND GRINDING WHEEL. Rubber wheels are bonded with special mixtures of rubber, and then vulcanized. Wheels of this class have substantially the same advantages as elastic wheels, except that they can be made harder and thinner to meet more severe conditions. Both elastic and vulcanized wheels are used for cutting off tubing, wire, thin sheets of steel or brass, and parts that are difficult to hold while cutting off with the commonly used tools. See also Bonding Processes for Grinding Wheels.

RUBBER PRODUCED ELECTRICALLY. Rubber articles may be produced electrically by a method like metal plating. The process consists in passing an electric current through a mixture of rubber latex, or uncoagulated milk of the rubber tree, with water, sulphur, fillers, accelerators, softeners, and other materials, according to the various requirements of the articles to be produced. The particles of rubber and other materials become charged electrically and are deposited together on molds of the desired shape, the same as copper or nickel is deposited on metal articles when plating. When the mixture of rubber and other ingredients is electrodeposited, the composition remains substantially unchanged during the coating, and the resulting rubber is of the same composition as the solution. Rubber is much easier to deposit than nickel, for with the same amount of electric current a coating 1400 times as thick as nickel-plating can be de-

posited. Rubber produced by this process has considerable strength, toughness, and resistance to deterioration with age.

RUBBER TURNING. Hard rubber is machined very effectively by the use of diamond tools. See Diamond Tools for Metal-cutting.

RUBBING MACHINE. Convex, flat, and concave surfaces of wood and metal can be sanded, rubbed, or otherwise finished and polished by means of a portable rubbing machine. This machine is made in both floor and ceiling types. The floor type consists of a stand on which is mounted a motor drive to a flexible shaft. The flexible shaft is connected to a rubbing head. The ceiling type also has a motor drive to a flexible shaft connected to a rubbing head. Either wet or dry rubbing can be performed. The rubbing head has two reciprocating pads which are arranged flexibly to permit working on surfaces of any contour. These pads are detachable.

RUGAN'S EXPERIMENTS. These were a series of experiments undertaken in England by Prof. H. F. Rugan for the purpose of determining the conditions connected with the growth of cast iron and its causes. See Cast-iron Growth.

RUHMKORFF COIL. The Ruhmkorff coil is an induction spark coil. The primary winding consists of a few turns of heavy wire and the secondary, of a large number of turns of fine wire. The current for the primary is usually supplied by battery cells, and in this circuit is inserted an interrupter which breaks the current as much as two hundred times per second. This causes a discharge of sparks to pass across a spark gap in the secondary when the current is broken. The device is used for igniting the charge in gas engines, etc.

RUN. The following are definitions of the term " run " as given by the National Tube Co.: (1) A length of pipe that is made of more than one piece of pipe. (2) The portion of any fitting having its ends " in line " or nearly so, in contradistinction to the branch or side opening, as of a tee. The two main openings of an elbow also indicate its run, and when there is a third opening on an elbow, the fitting is a side outlet or back outlet elbow, except that when all three openings are in one plane and the back outlet is in line with one of the run openings, the fitting is a heel outlet elbow or a single-sweep tee or sometimes a branch tee.

RUNNING BALANCE. When a part such as a drum, rotor, crankshaft, pulley, etc., is properly tested for balance while revolving, and any appreciable lack of balance is corrected on the basis of such test, the part is said to be in running or dynamic balance. Special balancing machines are used to determine the magnitude and location of unbalanced masses while the part

is revolving; hence the test is applied under operating conditions, which is not true of the test for static or standing balance.

RUNNING FLANGE. This is a central guide-link used on silent chains for keeping the chain on the wheel. This guide-link is inserted in every alternate link or pitch of the chain and a groove is turned on the wheel into which this link will fit. The running flange may also be provided at the outside edges of the chain, overlapping the edges of the wheel.

RUNNING ROPE. This term is applied to wire rope consisting of 6 strands with 12 wires each. It has a hemp core in the center of every strand with the 12 wires arranged around the core, and then a central hemp core about which the 6 strands are arranged. The construction produces a rope more flexible than the regular 6 by 19 hoisting rope, but for the same diameter the running rope has only two-thirds the strength of the hoisting rope. It is used for hawsers and mooring lines.

RUST. See Oxidation.

RUST JOINT. This is a kind of joint employed to secure a permanent connection that is either steam-, gas-, or water-tight connection. The joint is made by using a stiff paste which oxidizes the iron, the whole rusting together and hardening into a solid mass. It cannot generally be separated except by destroying some of the pieces. One recipe is 80 pounds of cast-iron borings or filings; 1 pound of sal-ammoniac; and 2 pounds of flowers of sulphur, mixed to a paste with water. See also Cements for Joints.

RUST PREVENTION. When the atmosphere, sea water, acids, or similar substances with which iron or steel comes into contact, attack the iron by forming oxides or rust upon its surface, corrosion is said to take place. Iron and steel cannot stand exposure to the atmosphere, particularly when excessive moisture is contained in the air, for any length of time, without the protection of some covering or coating which excludes the moisture and which, in itself, is not attacked by the influence of the atmosphere. The various preventatives which follow have been recommended by different men in the mechanical field.

Rosin and Oil. — Melt 4 ounces of rosin in 1 quart of linseed oil and mix with 2 gallons of kerosene oil. The mixture is readily applied with a cloth or brush, and can be easily removed.

Caoutchouc, Turpentine and Oil. — To preserve steel from rust, dissolve 1 part caoutchouc and 16 parts turpentine with a gentle heat, then add 8 parts boiled oil, and mix by bringing them to the heat of boiling water. Apply to the steel with a brush, the same as varnish. It can be removed again with a cloth soaked in turpentine.

Varnish and Turpentine. — To make a mixture that will prevent hardware

and machinists' tools from rusting, take one-half pint of Demar white varnish and mix it well with one gallon of turpentine. When the polished surfaces are thoroughly covered with a thin coat, the varnish will scarcely show, but will preserve the polish for years, if it is not scraped off with something very hard.

Vaseline and Blue Ointment. — In one pound of vaseline melt 2 ounces of blue ointment — what druggists call one-third — and add, to give it a pleasant odor, a few drops of oil of wintergreen, cinnamon, or sassafras. When thoroughly mixed, pour into a tin can. Keep a rag saturated with the preventive to wipe tools that are liable to rust.

Alcohol and Sperm Oil. — To make a preservative oil, use high test grain alcohol and best grade of sperm oil, equal parts. Keep in a tightly-corked bottle, and shake well before using, as the alcohol and oil separate after standing. Any moisture on a tool or gun at the time of application is quickly absorbed by the alcohol, which in a short time evaporates, leaving a good coat of sperm oil to protect the surface from rust.

Soda Solution. — Rust formation takes place on tools within a few hours after they have been hardened in brine or in any of the numerous hardening solutions containing different salts used for this purpose. To counteract this rusting of tools, they should be boiled in a strong solution of soda water for fifteen or twenty minutes after having been hardened. Sal soda (common washing soda) is the kind to use for the solution. A kettle holding about six or eight gallons of water may be used. About five pounds of soda are put in at the start, and after that about one to one and one-half pounds is added every day. In this way the strength of the solution is kept about right.

The addition of soda is necessary on account of the overflow which is required because of the method used for heating, the solution being brought to the boiling point by introducing steam. The work should always be boiled before being put into the tempering furnace and the latter should be at a temperature of about 212 degrees F., when the tools are changed from the soda kettle to the furnace. A basket arrangement with windlass may be used for raising and lowering the work, to prevent scalding the hands. The direction given, if followed, will prove of advantage in hardening and tempering tools, in that the formation of rust will be prevented.

Oil and Graphite. — To prevent screws from getting rusty and sticking tight, instead of using ordinary oil only, add some graphite. After years you will be able to unscrew them with ease, and find them as bright as new, even if they have been exposed to very damp air.

Camphor, Lard and Black Lead. — A formula for an anti-rust compound is made as follows: Dissolve 1 ounce of camphor in 1 pound of melted lard; take off the scum, and mix in as much fine black lead as will give it color.

Clean the machinery, and smear it with the mixture, and after 24 hours rub clean with a soft linen cloth. The machinery will keep clean, under ordinary circumstances, for a long time.

White Lead and Tallow. — In order to keep white lead and tallow soft in winter and summer alike, so that it can be applied with a brush to finished parts of machinery before shipping them, and for use in fitting keys, etc., prepare a mixture composed of five pounds of white lead and fifteen pounds of tallow. Heat this in a suitable receptacle, and stir until the ingredients are thoroughly mixed. Then remove the mixture to a cool place, and add two quarts of linseed oil, continuing to stir the composition until it becomes cold, as otherwise the white lead will settle at the bottom. This mixture will always remain of the same consistency at all temperatures.

Red-lead Paint for Structural Steel. — Structural steel is generally protected from rust by painting. A rust-retarding coat of paint may be suitably compounded from red lead mixed with pure linseed oil. The average stock mixture consists of from 25 to 30 pounds of red lead to a gallon of oil. This mixture can be reduced to the proper consistency at the time of application. A small amount of turpentine added to this brush coating will greatly assist in its manipulation, and will also provide for proper penetration. Red lead should be mixed at the time of its application, as it settles quite readily, being an extremely heavy pigment.

RUST REMOVAL. Tools which have become very rusty may be treated with a chemical solution, instead of trying to scour the rust off by means of an abrasive cloth. A good solution for removing rust may be made as follows: Into one quart of distilled water dissolve, little by little, sufficient chloride of tin to obtain a saturated solution, that is, until the water will not dissolve any more of the salts. Put the tool into a receptacle containing the solution and let it stand overnight. In the morning rinse the solution off in running water and dry thoroughly with a piece of chamois or cloth.

Sweet Oil and Lime. — A good method for removing rust from steel is to first rub the object with sweet oil, and then, after a day or two, rub it with finely powdered unslaked lime until the rust disappears. Then give it again a coating of oil with a woolen cloth, and put it in a dry place.

Tin Putty, Buckshorn, and Spirits of Wine. — It quite frequently happens that parts of machinery having polished surfaces become rusty. This rust is difficult to remove without scratching the highly polished surface. A very effective mixture for removing rust from such surfaces without injury may be made as follows: Ten parts of tin putty (putty-powder or jewelers' putty), 8 parts of prepared buckshorn, and 250 parts of spirits of wine. These ingredients are mixed to a soft paste, and rubbed in on the surface until the rust disappears. When no trace of rust seems to remain, the surface is polished with a dry, soft cloth.

Sulphuric Acid. — Rust may be removed from small steel parts such as screws, nuts, pins, etc., when they are not badly pitted, by dipping them into a dilute solution of sulphuric acid. To prepare the acid bath, pour the acid, little by little, into a bowl partly filled with water. After each addition of acid, try one of the rusted parts, and continue trying until the proper strength is obtained to eat the rust off clean. Let the parts remain in the acid bath until cleaned of rust, then remove and wash in soda water, and then in benzine. Finally, dry the parts and brighten in sawdust.

Muriatic Acid. — A quick method of removing rust from steel parts, which is not generally known to machinists, is outlined in the following: Rub the surface of the piece of work from which rust is to be removed with muriatic acid. A convenient way to do this is to dip a small stick into the acid and rub it over the surface of the work. This procedure is continued for several minutes, dipping the stick in as often as necessary to obtain a sufficient quantity of acid. After this treatment has been completed, the work should be washed with a solution of common washing soda and water and then dried in sawdust.

Removing Rust before Electroplating. — A simple method of removing rust from surfaces that are afterwards to be electroplated consists in dipping the articles first into a strong hot potash bath, for about half an hour, and then in a cold muriatic-acid pickling solution, composed of 2 parts of water to 1 of acid. This solution removes the rust in a few minutes, leaving the metal apparently attacked but very little. The previous soaking in the strong hot potash solution is responsible for this rapid pickling, as tests have shown that, without previous dipping, 65 minutes is required by the acid bath, against four minutes when previously treated in the potash bath.

RUST RESISTANCE OF IRON AND STEEL. Silicon in iron increases greatly its tendency to corrode; 0.3 per cent of silicon will make iron rust 20 per cent more rapidly than would ordinary iron free from silicon. On the other hand, alloying steel with nickel or copper gives it increased resistance to corrosion; 0.20 per cent of copper in steel produces a material which is attacked by acids at one-tenth the rate of ordinary iron. The corrosion in the atmosphere is only one-third that of iron free from copper. An increase of copper above 0.20 per cent does not add to the corrosion resisting qualities of the iron.

These results have been obtained not merely by laboratory experiments, but in practice. Roofs have been covered in and around Pittsburg with ordinary sheet steel and also with a sheet steel containing 0.20 per cent of copper. The copper alloy roofs were in good condition when the ordinary sheet iron roofs were completely corroded. These experiments also showed that the metals are less attacked in rural districts than in cities, which, probably, is due to the carbon and acid fumes present in the city atmosphere.

SABIN PROCESS. The Sabin process is a method used for coating pipe in order to protect it against moisture. The coating consists of a mixture of asphaltum and linseed oil. After having been dipped in this coating, the pipe is allowed to drain for about half an hour, and is then baked in an oven at a temperature of about 300 degrees F. for two hours.

SADDLE. A machine tool saddle is a slide which is mounted upon the ways of a bed, cross-rail, arm, or other guiding surfaces, and the saddle usually supports one or more secondary slides for holding either metal-cutting tools or a work-holding table. On a knee-type milling machine the saddle is that part which slides upon the knee and which supports the work-holding table. The saddle of a planer or boring mill is mounted upon the cross-rail and supports the tool-holding slide. The saddle of a lathe is that part of a carriage which slides directly upon the lathe bed and supports the cross-slide.

SADDLE KEY. This form of key has parallel sides and is curved on its under side to fit the shaft. It is slightly tapered on top so that, when it is driven tightly in place, the shaft is held by frictional resistance. This key should be fitted so that it bears lightly on the sides and heavily between the shaft and hub throughout its entire length. As the drive with this type of key is not positive, it is only used where there is little power to transmit. It is an inexpensive method of keying, as the shaft does not need to be machined.

S. A. E. STANDARD SCREW THREADS. The Society of Automotive Engineers, Inc., (S. A. E.) screw thread standard is the same as the United States standard or the American standard in regard to the thread form. The S. A. E. (American) standard has three series of pitches, known respectively, as coarse, fine, and extra fine. The coarse and fine series are the same as the American standard and, like the latter, the sizes of the smaller screws ranging from 0.060 inch to 0.216 inch, are designated by numbers 0, 1, 2, 3, etc. The larger sizes are designated by fractions or fractions and whole numbers.

The coarse screw thread series is intended for bolts and screws (1) where jar and vibration are not important factors; (2) where an average tensile strength is required; (3) where it is necessary to dismantle frequently and under unfavorable conditions; (4) where, in the case of cap-screws, the holes in which the screws are inserted are tapped in metals other than steel.

The fine series is intended for finished bolts and screws (1) where jar and vibration are important factors; (2) where the tensile strength required is above the average; (3) where a fine adjustment is required, especially when castle nuts are used; (4) where holes for cap-screws are tapped in steel.

The extra fine series was adopted in 1915 as the S. A. E. fine series for aeronautical and other applications where screw threads finer than the present S. A. E. fine-screw thread series are necessary.

SAFETY COUPLING. A safety coupling is a coupling so arranged that, if the power to be transmitted exceeds the normal requirements, the driven member will be permitted to slip.

SAFETY VALVES. The object of a safety valve is to prevent the pressure of steam or other gases from rising to the danger point. A safety valve must be so made that the effective opening will be sufficiently large to discharge all the steam or gas which is being generated. The pressure at which the valve opens may be under the control of a lever and adjustable weight, or a spring may be used to hold the valve proper upon its seat until the pressure increases to the point where the valve should open. An essential point in the design of spring-operated "pop safety valves" is that the arrangement must be such that no cramp will be developed, due to the unequal seating of the spring. Ball-and-socket bearings may be provided for the spring collars in order to equalize the thrust of the spring. By means of an adjusting ring the valve can be so set that it will reduce the pressure as desired. Thus a pop safety valve can be set so that it will blow off at 100 pounds pressure and close again when the pressure is reduced to 98 pounds. By turning the adjusting ring up or down, the amount of pressure reduction can be regulated to suit conditions. If the valve does not reduce the pressure sufficiently, the ring should be turned up so that it causes the valve to lift higher and remain longer off of its seat. The noise of escaping steam is lessened, on the locomotive type of pop valve by the use of a muffler. The form of muffler used, generally consists of outer and inner shells which are pierced with a series of holes so arranged as to divert and break up the exhaust steam as it comes from the valve, in such a way as to finally allow it to escape into the atmosphere with very little noise.

SAND BLASTING. The foundry sand-blast was developed for the cleaning of castings, and its advantages for cleaning or surfacing in many branches of metal working, plating, and finishing have been so fully demonstrated, that it has become an important process in different lines of manufacture. Thoroughly sand-blasted castings can be machined more rapidly and at reduced expense. In sand-blasting, sand or some other abrasive is forced through a nozzle, under pressure, against the surface to be treated. The sand-blast machine may have single or multiple nozzles, the size of each opening, together with the pressure maintained, governing the air volume required. The sand-blasting process is used, not only in cleaning iron and steel castings, but also for brass and aluminum, when the pressure and nozzles are properly adapted to these softer materials. Sheet-metal parts

are frequently prepared for plating, galvanizing, enameling, or painting by sand-blasting. The process is also employed for matt-surfacing metals, roughing handles of instruments, lettering or frosting glass, lettering marble, blasting wood for the purpose of bringing out the grain, and many other uses too numerous to mention here.

Air, compressed to varying pressures, is commonly employed in all sand-blasting equipments, but the pressure is applied in different ways. The three systems in use are generally designated as the direct-pressure system, the suction or syphon system, and the gravity system. In the direct-pressure system the air and the abrasive are combined in and discharged from a closed tank through a nozzle. In the suction system, the abrasive is carried to the nozzle by a suction created by a jet of compressed air, which, in passing through the nozzle, carries the abrasive with it. In the gravity system, the abrasive is carried by mechanical means to a place above the nozzle and is fed down by gravity. At the nozzle, the abrasive and compressed air combine and are discharged. For some classes of work a small nozzle opening, that is, a fine strong jet, may be desirable; for other work a broader stream, covering a larger surface but working at a lower pressure may be best. The pressure that should be used depends upon the nature of the work. The following figures will give an idea of the pressures generally used. For cleaning light castings, such as stove castings, etc., use from 5 to 10 pounds; for medium- and heavy-grade iron castings, from 15 to 20 pounds; for steel castings, from 30 to 75 pounds; for buildings and steel structures, from 5 to 30 pounds, depending upon the height.

SAND-BLASTING ABRASIVES. Sand is the most commonly used abrasive for sand-blasting on account of its relatively low price. Ordinary lake or river sand is inferior to sea sand and silica sand, as the two latter possess greater hardness and are therefore more lasting. River sand results in more or less dust, and it disintegrates rapidly. Abrasives such as steel grit and shot are used to a certain extent, and the use of these more expensive abrasives is warranted under certain conditions. For classes of work such as electroplating or galvanizing, the metallic dust adhering to the work would make its use prohibitive, because it prevents perfect galvanizing, although no difficulty is experienced in this respect with sand. There is no one abrasive that is best adapted to all classes of work. A selection must be made with due regard to reclaiming means, to greatest economy in operation, and to maximum production. All abrasives should be screened each time before using, to remove particles large enough to clog the nozzle, and also to eliminate fine particles which only produce dust and have no abrasive quality, but which consume some of the pressure. Screen separators, frequently operated by compressed air, may be used for this purpose.

SAND-BLAST ABRASIVE SCREENS. In reference to screens for sand-blast abrasives, the number of the mesh gives the number of openings to the linear inch. For example, No. 10 mesh means that there are ten openings or meshes to the inch, or one hundred openings to the square inch. Ocean sands which are largely used in the eastern states, would be graded about as follows:

Sand No.	Passes Screen	Remains on Screen
1	20 mesh	40 mesh
2	14 mesh	20 mesh
3	8 mesh	14 mesh
4	5 mesh	8 mesh

The weight of the wire used for the screens is governed by the weight and character of the material to be screened, so that the size or gage of the wire often varies for the same number of screen, and this, in turn, somewhat determines the size of the openings or meshes. The nature of the sand-blast apparatus is such that precise grading is not necessary.

SAND-BUFFING. See Buffing.

SAND-HOLE. In a casting, a sand-hole is a section of the casting in which sand has been entrapped. The sand is eroded from the mold by the entering current of molten iron and floats to the top, but the iron may have been partially solidified before the sand reaches the top, and as a result it will remain imprisoned in the body of the casting. Occasionally large cavities are formed in this way which impair the strength of the casting.

SANDING MACHINE. These are wood-working machines and they are made in two general types: The revolving disk or face plate type and the traveling belt type. Both are faced with sand paper or other abrasive material. The stock is smoothed by bringing it in contact with the working surface. The disk machine is the one usually found in the pattern shops.

SAND, MOLDING. See Molding Sand.

SAPONIFICATION VALUE OF OIL. The saponification value of an oil is the number of milligrams of caustic potash required to completely saponify one gram of the fat or oil. A low saponification value generally indicates adulteration with mineral oil.

SATURATED AIR. See Air, Saturated.

SAWDUST AS A FIRE EXTINGUISHER. Sawdust is effective for extinguishing small fires in oils and other inflammable liquids. This is due to the fact that the sawdust-particles pack together closely, and prevent the air from penetrating the surface freely enough to actively support the com-

bustion beneath; thus sawdust smothers the flames in the same manner as a blanket, by excluding the air. Sawdust may be successfully used for extinguishing burning gasoline that has been spilled on floors or on the ground; but it is of comparatively little value in the treatment of gasoline fires in large tanks, because it is almost impossible to spread the sawdust over the entire surface before some of it sinks to the bottom, exposing the surface at these points and allowing the liquid to reignite. It is far more useful in connection with liquids such as heavy oils, lacquer, japan, and melted wax, because it floats upon the surface of fluids of this type, and blankets them quite effectually. The value of sawdust as an extinguishing agent can be considerably increased by the addition of a certain proportion of bicarbonate of soda (generally known as "baking soda"). This substance, when exposed to heat, gives off carbon dioxide gas, which materially assists in preventing the access of air. A mixture composed of 10 pounds of bicarbonate to 1 bushel of sawdust has proved satisfactory, and tests have shown that by the use of this mixture fires may be extinguished more quickly and with a smaller amount of material than when sawdust is used alone.

SCABBINESS. Scabbiness is a defect on the surface of castings caused by the erosive action of the molten metal on the mold, the iron eating away fillets or partitions or scouring away patches of sand as it flows into the mold. As a result, the casting will not be of the proper form, but will have its angles partly filled up and unsightly projections on its surface.

SCAFFOLDING. In blast-furnace practice, scaffolding is a common difficulty in which some of the material in the furnace, instead of descending uniformly, sticks to one side of the furnace and gradually is built up as a pasty mass. Scaffolding is also caused by irregularity in the lining of the furnace due to uneven wear. Sometimes a part of a scaffold breaks off and falls to the hearth, interfering with the working of the furnace.

SCALE ANNEALING FURNACE. This is a type of furnace used in connection with the cold-rolling of sheet metal, in which the coils of sheet steel are exposed to the action of an oxidizing atmosphere while being heated. This method of annealing is only employed in the case of steel which has been decarburized on the surface, and the "scale anneal" serves to remove the decarburized metal.

SCALE, BOILER. See Boiler Scale.

SCALE FOR DRAFTSMEN. Ordinarily, the draftsman's scale is either flat, with beveled edges, or triangular, with the flat sides relieved by semicircular grooves. There are two classes of graduations. The first includes graduations for "full-size" drawings, that is, drawings made exactly the same size as the actual parts they represent, and second, graduations that

are adapted for drawings made on a scale much smaller than the parts represented. In the first class, the inches are divided into eighths, sixteenths, thirty-seconds, and sixty-fourths, or tenths and hundredths; in the second, graduations are made to a reduced scale. Thus $1\frac{1}{2}$, 3, or 6 inches on the scale may represent one foot. These are the ordinary scales used by mechanical draftsmen.

SCALE SENSIBILITY. The quality of accuracy in a weighing scale is not alone sufficient to insure its suitability for a given purpose. It must also have a proper sensibility. The sensibility of a scale or of any engineering instrument is its ability to respond to small variations in the quantity which it is to measure. It is usually expressed in terms of the distance or angle traversed by the pointer or other reading or indicating device for a unit change in the quantity being measured. In a weighing-scale, it is found convenient and advantageous for a number of reasons to invert the ratio and use the term " sensibility reciprocal." In scales provided with a beam and trig-loop, the sensibility reciprocal is the weight required to be placed upon the platform to turn the beam from a horizontal position of equilibrium in the middle of the trig-loop to a position of equilibrium at the top of the loop." The sensibility reciprocal may be determined by subtracting the weight instead of adding it, thereby causing the beam to assume a position of equilibrium at the bottom of the loop; or, indirectly, by moving the sliding poise on the beam the required amount in either direction, to obtain the specified change in the position of equilibrium of the beam; or by adding or subtracting small weights to or from the counterpoise until the specified change is obtained, and determining the equivalent of the small weights used, in terms of weight on the platform.

The sensibility and accuracy of scales are often confused, as the user is likely to assume that a scale which responds readily to slight changes of load is an accurate scale. The sensibility of a scale is not directly a measure of its accuracy. It indicates only to what degree of precision readings may be taken, provided proper allowance be made for the error or correction of the scale at that reading, the effect of friction being considered eliminated. The factors which determine the sensibility of a platform scale or of any scale, in which the reading is obtained through the operation of a lever system oscillating about a definite position of equilibrium, are given by a very complex expression. Within certain limitations, however, the sensibility, which in practice is controlled by an adjustment of the beam of a scale, increases with: 1. Increasing length of beam. 2. Decreasing weight of beam. 3. Decrease of distance at which center of gravity of beam lies below its center or fulcrum knife-edge. 4. Decrease of multiplication or leverage ratio of scale.

SCALPING OF CRUCIBLES. Although crucibles are free from moisture when removed from the kiln, they rapidly absorb it, and many take up 5 per cent of moisture during shipment from maker to user. If, instead of eliminating the moisture by a gradual annealing, the damp crucible is put directly into a hot furnace, or into a cold one and heated too rapidly, the moisture will be changed into steam so that the steam evolved will blow pieces of the crucible off bodily; that is, the crucible will "scalp." To prevent this, it must be raised very gradually from room temperature to a temperature somewhat above the boiling point of water, so that the moisture may be slowly driven off without "scalping."

SCHIELE CURVE. Same as Tractrix.

SCIENTIFIC MANAGEMENT. In general, scientific management aims to correlate and systematize all the best modern methods and developments in factory administration and work, and to adhere strictly to the results of investigations carried out in a scientific manner. Management under this system is not content to rely upon records or upon the judgment of the most experienced workmen, but brings to its aid all the resources of scientific investigation. Methods of performing work are carefully analyzed, and the best elements of all of these combined in order to develop a new method. Having established the best methods, workmen under scientific management are instructed in regard to approved methods of working, and some incentive or reward is offered for carrying out the work in the prescribed manner.

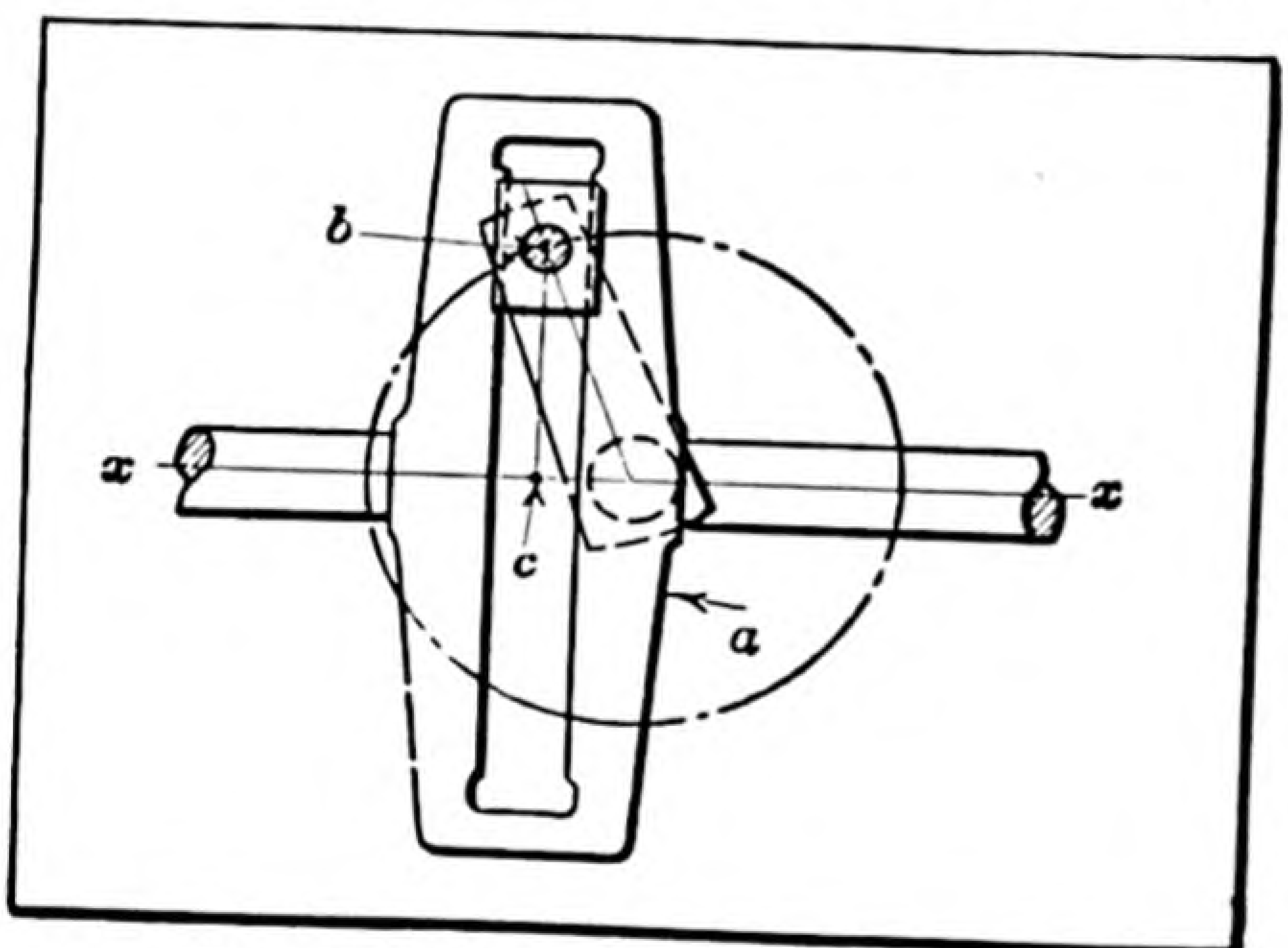
SCLEROMETER. The Turner sclerometer is an instrument for testing hardness, which is adapted primarily for laboratory use. A diamond point is used to scratch a line on the work under a known pressure, after which the width of this line is read and converted into arbitrary figures. The work must have a bright surface to facilitate reading. The operation is slow, but this method allows minute laboratory studies to be made.

SCLEROSCOPE. The scleroscope is an instrument which measures tne hardness of the work in arbitrary terms of elasticity. A diamond-tipped hammer is allowed to drop from a known height on the metal to be tested. As this hammer strikes the metal, it rebounds, and the harder the metal, the greater the rebound. The extreme height of the rebound is noted, or with the latest type of machine, recorded, and an average of a number of readings taken on a single piece will give a good indication of the hardness of the work. The surface smoothness of the work affects the reading of the instrument, and between a filed surface and a surface on the same work polished with F.F. alundum there is a difference of ten points. The readings are also affected by the contour and mass of the work and the depth of the case,

in carburized work, the soft core of light-depth carburizing, pack-hardening, or cyanide hardening, absorbing the force of the hammer fall and decreasing the rebound. The hammer weighs about 40 grains, the height of the rebound of hardened steel is in the neighborhood of 100 on the scale, or about $6\frac{1}{4}$ inches, while the total fall is about 10 inches or 255 millimeters.

SCLEROSCOPE OF DIAL TYPE. This improved type of instrument is provided with a dial, the hand of which remains fixed an indefinite length of time after making a test, instead of obtaining a momentary reading as with the older design of scleroscope. The hammer differs from that of the earlier models in that it is longer, heavier, and drops and rebounds a comparatively short distance. The hardness values obtained with this instrument agree with those indicated by the vertical scale of the older design.

SCOTCH YOKE. The irregularity in the motion of a cross-head of an engine relative to its crank in the simple form of crank mechanism, which irregularity is due to the fact that one-half of the crankpin circle curves toward the cross-head, whereas the other half curves away from it, has an important effect on the design of steam-engine valve-gears, and it is objectionable in some types of mechanism. A simple form of mechanism for eliminating the irregularity of cross-head motion is known as a "crank and slotted cross-head" or the *Scotch yoke.*

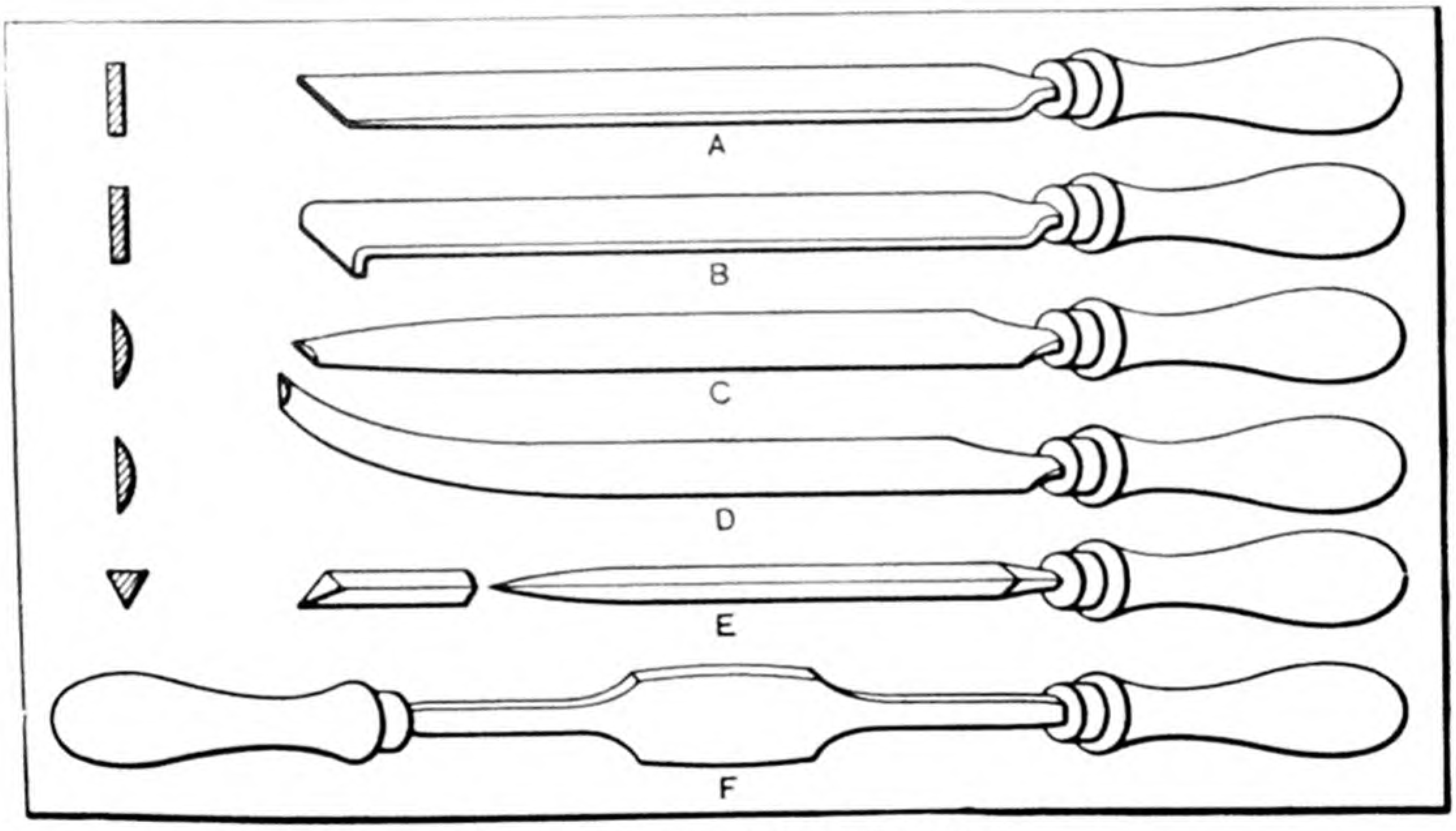


Scotch Yoke or Slotted Cross-head

The cross-head *a* (see diagram) has a slot which is at right angles to the center-line *xx* representing the direction of rectilinear movement. The crankpin carries a block, which is a sliding fit in this slot, and is free to revolve about the pin. As the crank revolves, the distance which the crankpin moves, as measured in a horizontal direction, will be the same as the movement of the cross-head. This mechanism is sometimes called a *harmonic motion,* because if the crank rotates uniformly, the cross-head will be given a harmonic motion. When a point, as at *b*, moves with uniform velocity along a circular path, point *c* will have a harmonic motion along the center-line *xx*.

SCRAPING MACHINE PARTS. In metal working, slight errors in plane or curved surfaces are often corrected by the use of hand scrapers; scraping is also employed to produce ornamental effects on exposed sur-

faces. For correcting errors, the part to be scraped is ordinarily applied to whatever surface it is being fitted; the bearing marks or " high spots " are then noted and removed by scraping. By repeatedly obtaining these bearing marks and then removing them, a more evenly distributed bearing is secured. In this way, bearing boxes are often fitted to their shafts after having been bored. Small flat surfaces are scraped to make them more accurate, the method being to first apply the work to a standard surface plate, note the bearing marks and, if there is unevenness, correct the error by scraping. In fitting two flat parts together, it is common practice to first scrape one member to secure as true a surface as possible, and then use it as a standard while fitting the other part. In order to make the bearing marks



Different Forms of Hand Scrapers

show clearly, some kind of red or black marking material is generally used. A thin coating is applied to the bearing shaft, surface plate, or whatever surface the work is to be scraped to fit. The work is then rubbed over this surface and the marking material shows just where the high spots are. It is important to keep the marking material in a covered box in order to exclude all grit or chips. The scraper should be made " glass hard " and be given a fine edge by the use of an oilstone. The materials commonly used to show the bearing marks are oil mixed with lampblack, Prussian blue, or red lead.

Scrapers. — The different forms of scrapers commonly used in fitting machine parts etc., are shown by the accompanying illustration. The *flat scraper A* is almost invariably used for plane surfaces. For ordinary purposes, the scraper blade is about $\frac{3}{16}$ inch thick, from 1 to $1\frac{1}{4}$ inch wide, and

is drawn out at the point to a thickness of about $\frac{1}{16}$ inch. The cutting end is as hard as possible and is rounded slightly, in grinding, so that the outer corners will not score the surface being scraped. The grinding should be done, preferably, on a wet grindstone, the edge being finished with an oilstone. The *hook scraper B* is also used on flat surfaces. It is preferred by some workmen for obtaining a fine, smooth surface and can be used, occasionally, in narrow spaces where there would not be room enough for a straight, flat scraper. Straight and curved scrapers of the "half-round" type are shown at *C* and *D*. These are used for scraping bearings, etc., the sides forming the cutting edges. The curved type *D* is more convenient to use on large half-bearings, as it is held at an angle and the scraping is done by the curved edge. The *three-cornered* or *three-square scraper* shown at *E* is also used to some extent on curved surfaces. When the end is beveled, as shown in the detail view to the left, this form of scraper is convenient for producing sharp corners or for "relieving" them slightly. The *two-handled scraper* shown at *F* is an excellent form for scraping bearing boxes and all curved surfaces which are so located that this type can be used. This style of scraper is much superior to the forms shown at *C* and *D*, especially for large work. The straight or curved half-round type works very well on soft bearing metals such as babbitt metal, but on brass or bronze, it cuts slowly and, as soon as the edge is slightly dulled, considerable downward pressure is necessary. The type *F* requires very much less effort on the part of the workman, and it will cut rapidly. As there are two handles instead of a single handle at one end, the blade can be pressed against the work with little exertion. This form of scraper is largely used for the heavy scraping required in fitting large connecting-rod brasses, etc. The sides are sometimes ground slightly concave (to give the cutting edges "rake") by holding them against the face of the grinding wheel.

Spotter. — Flat finished surfaces on the ways of machine tools, etc., are often finished by spotting, frosting or flaking, partly to obtain an ornamental appearance and also because the spotted surface holds lubricant more effectively. One type of spotter placed on the market is so arranged that the scraper, as it is pushed across a guide placed upon the work, receives a rocking motion so that the blade produces a uniform half-moon effect without skill or experience on the part of the workman. By adjusting a small thumb screw, different shaped spots may be obtained.

SCRAPING, POWER. For scraping flat surfaces on machine tools to an accurate bearing, a power scraper is efficient. The scraper tool of a design on the market, is mounted on an arm, and a reciprocating movement is imparted to it by a rack and pinion drive. The motor is coupled to the scraper tool through gears and clutches in such a manner that when the operator pushes a control sleeve forward, the scraper tool is driven forward.

When the operator pulls the sleeve backward at the end of the forward stroke, a reverse drive is engaged to pull the tool back. With this arrangement, the scraper is operated in the same manner as a hand tool, except that no manual effort is required. With the sleeve held forward or back, any desired length of stroke may be imparted to the scraper tool. The forward stroke is at the rate of 60 feet per minute, and the return stroke at the rate of 90 feet per minute. With the sleeve in the neutral position, the drive is disengaged and the scraper arm can be pulled forward or pushed back over a range of 5 feet, in order to bring the tool into the required position. With a machine of this type, it is possible to scrape faster than by hand, and the fatigue factor is entirely eliminated. The arm on which the scraper tool is mounted can be instantly pushed or pulled the length of 5 feet. There is also a power-driven screw, engaged by means of a hand-lever, which provides for raising or lowering the head to bring the tool to the most convenient angle for scraping. A ball-bearing swivel on the column permits the tool to be easily swung around a complete circle.

SCRAP VALUE. The scrap value of a machine is the actual cash return brought by the sale of the materials (iron, copper, etc.) of which the machine is made, at current market prices, less cost of junking. The cost of junking will be high in the case of large and unwieldy machines, and, in some cases, will offset the return from sale of scrap, making the net scrap value zero or even a negative quantity.

SCREW. A screw may be defined as a cylinder around which a thread is wound in successive coils or helices, all turns being equally spaced. The lead of a single-threaded screw is the distance between like points on successive threads measured on a line parallel to the axis of the screw. The amount that a screw advances in one turn is equal to the lead, and in fractional turns it is equal to the same fraction of the lead; thus, if a screw is given one-fourth turn, it advances one-fourth of the lead. Considered as a machine element, the screw is classed as one of the " mechanical powers." In the case of the screw, the initial force, tending to turn it, moves through the circumference of a circle, the point of application usually being at the end of a crank or bar, at the surface of a pulley or handwheel. Hence, the applied force multiplied by the circumference of the circle described by the force equals the resistance multiplied by the lead.

SCREW BRAKE. This is an automatic mechanical brake used largely on overhead traveling cranes. It is so arranged that when lifting the load the whole brake revolves without resistance, but as soon as the lifting effort ceases and a slight reverse has taken place, the load is held securely by friction. In order to lower the load, the motor must be reversed, thus reducing the pressure on the friction faces and allowing the load to slip steadily.

SCREW CONVEYORS. The screw or worm conveyor is one of the oldest types. Modern screw conveyors are built up of sectional screw flights, that are fixed to a central shaft or spindle by means of its shank, which is tapped and fitted with a nut. The spindle is usually made of steam pipe in lengths of about 8 feet, the different lengths being coupled together. The continuous screw conveyor consists of a spindle and screw all rolled in one continuous screw into sections of about 10 feet. Screw conveyors are fitted into a wooden or steel trough, so as to leave a clearance of between $\frac{1}{8}$ and $\frac{1}{4}$ inch. Too long a run should not be used for the conveyor without "breaking in" for a drive — say, not over 200 feet for a 6-inch screw, and not over 300 feet for a 9-inch screw conveyor. If possible, the drive should always be placed so as to pull the material toward the drive instead of pushing the material away from the drive.

SCREW-DRIVING MACHINE. For driving either wood screws or machine screws in large numbers, a power-driven automatic screw-driving machine is efficient. In the operation of the Reynold's machine the screws are thrown at random into a magazine from which they are delivered through an inclined chute to the lower end of the spindle, in the proper position for driving. As the spindle is lowered by operating a foot lever, a screw driver bit in the spindle engages the screw lost and drives the screw with great rapidity.

SCREW MACHINES AND TURRET LATHES. When a machine is referred to as a turret lathe, this is generally understood to be a horizontal machine designed either for handling bar stock, chuck work, or both for bar and chuck work, and the turret may or may not have a power-feeding movement. A turret lathe that is designed more particularly for turning comparatively small screws, pins, etc., from steel rods or bar stock, is commonly (although not invariably) known as a *hand screw machine*, or as a *turret screw machine*. According to the practice of some manufacturers, the name screw machine is applied to small turret lathes which have a collet chuck in the spindle and a "wire feed" or a mechanism for feeding a wire rod or bar stock through the spindle. When the machine is intended for either bar or chuck work, or for chuck work exclusively, the name turret lathe is commonly used, and such a machine may or may not have a stock-feeding mechanism which operates in conjunction with the spindle chuck. The foregoing method of distinguishing between the two types, however, is not universal, and there is no general agreement in the use of these names. See also Automatic Screw Machine.

SCREW MACHINE TAPS. The taps known in the tap manufacturing business as *screw machine taps* are, as the name indicates, used for tapping in automatic screw machines. The thread to be cut is usually short and

the taps, therefore, are essentially different from other taps used for nut tapping in machines. The chamfered end of the thread of these taps is usually very short, as in most cases the tap is required to tap down to the bottom of a hole. The thread is relieved only on the top of the thread of the chamfered portion.

SCREW PITCH GAGE. This type of gage is used for determining the number of threads per inch on a screw, and consists of a holder which has pivoted at each end a number of leaves that are notched to conform to different thread pitches, the number of threads being stamped upon each leaf.

SCREW PUMP. The screw pump is a special form of the rotary type. One design has two parallel shafts and on each shaft there are right- and left-hand screws of coarse pitch so arranged that the threads of one screw mesh with the thread groove of the screw on the opposite shaft. These screws fit closely into the pump casing or cylinder. When the pump is in operation, the liquid flows from the suction pipe to the two ends of the cylinder and is forced toward the center by the action of the two pairs of intermeshing threads, the discharge being at the center and on the opposite side from the suction opening.

SCREWS, COLLAR-HEAD. See Collar-head Screws.

SCREW, SELF-TAPPING. See Self-tapping Screw.

SCREWS, MULTIPLE. Considerable confusion is often caused by indefinite designation of multiple-thread (double, triple, quadruple, etc.) screws. One way of expressing that a double-thread screw is required is to say, for instance: "3 threads per inch double," which means that the screw is cut with 3 *double* threads, or 6 threads per inch, counting the threads by a scale placed alongside of the screw. The pitch of this screw is $\frac{1}{6}$ inch, and the lead twice this, or $\frac{1}{3}$ inch. To cut this screw, the lathe will be geared to cut 3 threads per inch, but the thread will be cut only to the depth required for 6 threads per inch. "Four threads per inch triple" means that there are 4 times 3, or 12 threads along one inch of the screw, when counted by a scale; the pitch of the screw is $\frac{1}{12}$ inch, but, being a triple screw, the lead of the thread is 3 times the pitch, or $\frac{1}{4}$ inch. The best way of expressing that a multiple-thread screw is to be cut, when the lead and the pitch have been figured, is, for example: "$\frac{1}{4}$ inch lead, $\frac{1}{12}$ inch pitch, triple thread."

SCREWS, POWER TRANSMISSION. The square form of thread has a somewhat higher efficiency than threads with sloping sides, although when the angle of the thread form is comparatively small, as in the case of an Acme thread, there is little increase in frictional losses. The Acme thread has superseded the square form on many classes of equipment requiring lead-screws or other power transmitting screws, because the former has practical

advantages in regard to cutting and also in compensating for wear between the screw and nut. Multiple-thread screws are much more efficient than single-thread screws, as the efficiency is affected by the helix angle of the thread.

Notation Used in Formulas. — The notation which follows applies to the formulas in the next paragraph. F = force applied at end of lever-arm; L = load moved by screw; R = length of lever-arm; l = lead of screw thread; r = mean or pitch radius of screw; μ = coefficient of friction.

Force Required to Turn Screw. — In determining the force which must be applied at the end of a given lever-arm in order to turn a screw (or nut surrounding it), there are two conditions to be considered: (1) When rotation is such that the load *resists* the movement of the screw, as in raising a load with a screw jack; (2) when rotation is such that the load *assists* the movement of the screw, as in lowering a load. When load resists screw movement:

$$F = L \times \frac{l + 2\,r\,3.1416\,\mu}{2\,r\,3.1416 - \mu l} \times \frac{r}{R}$$

When load assists screw movement:

$$F = L \times \frac{2\,r\,3.1416\,\mu - l}{2\,r\,3.1416 + \mu l} \times \frac{r}{R}$$

If lead l is large in proportion to the diameter so that the helix angle is large, F will have a negative value, which indicates that the screw will turn due to the load alone, unless prevented by a force F which is great enough to prevent rotation of a non-locking screw.

Coefficients of Friction. — According to experiments by Professor Kingsbury made with square-threaded screws, a coefficient of 0.10 is about right for pressures less than 3000 pounds per square inch and velocities above 50 feet per minute, assuming that fair lubrication is maintained. If the pressures vary from 3000 to 10,000 pounds per square inch, a coefficient of 0.15 is recommended for low velocities. The coefficient of friction varies according to lubrication and the materials used for the screw and nut. For pressures of 3000 pounds per square inch and using heavy machinery oil as a lubricant, the coefficients were as follows: Mild steel screw and cast-iron nut, 0.132; mild steel nut, 0.147; cast brass nut, 0.127. For pressures of 10,000 pounds per square inch using a mild steel screw, the coefficients were, for a cast-iron nut, 0.136; for a mild steel nut, 0.141; for a cast brass nut, 0.136. For dry screws, the coefficient may be 0.3 to 0.4 or higher.

Coefficient of Friction for Angular Thread Forms. — Frictional resistance is proportional to the normal pressure, and for a thread of angular form, the increase in the coefficient of friction is equivalent practically to $\mu \sec \beta$, in

which β equals one-half the included thread angle; hence, for a U. S. Standard thread, a coefficient of 1.155 μ may be used.

Effect of Helix Angle on Efficiency. The efficiency between a screw and nut increases quite rapidly for helix angles up to 10 or 15 degrees (measured from a plane perpendicular to the screw axis). The efficiency remains nearly constant for angles between about 25 and 65 degrees, and the angle of maximum efficiency is between 40 and 50 degrees. A screw will not be self-locking if the efficiency exceeds 50 per cent. For example, the screw of a jack or other lifting or hoisting appliance would turn under the action of the load if the efficiency were over 50 per cent. It is evident that maximum efficiency for power transmission screws often is impracticable, as for example, when the smaller helix angles are required to permit moving a given load by the application of a smaller force or turning moment than would be needed for a multiple screw thread.

Efficiency Formula. — In determining the efficiency of a screw and a nut, the helix angle of the thread and the coefficient of friction are the important factors. If E equals the efficiency, A equals the helix angle, measured from a plane perpendicular to the screw axis, and μ equals the coefficient of friction between the screw thread and nut, then the efficiency may be determined by the following formula, which does not take into account any additional friction losses, such as may occur between a thrust collar and its bearing surfaces:

$$E = \frac{\tan A\ (1 - \mu \tan A)}{\tan A + \mu}$$

This formula would be suitable for a screw having ball-bearing thrust collars. Where collar friction should be taken into account, a fair approximation may be obtained by changing the denominator of the foregoing formula to $\tan A + 2\mu$. Otherwise the formula remains the same.

SCREW STOCK. Low-carbon steel commonly known as "screw stock" usually has the following composition: Carbon, from 0.08 to 0.25 per cent; manganese, from 0.60 to 0.90 per cent; phosphorus, not over 0.13 per cent; and sulphur, from 0.075 to 0.15 per cent. This steel should not be used for machine parts which require great strength or roughness. Screws made from it should be heat-treated. The steel is made in the form of both cold-rolled and hot-rolled bars, the cold-rolled bars being much stronger. Screw stock is generally heat-treated by heating to 1500 degrees F. and quenching it in water or oil, after which it is reheated to from 600 to 1300 degrees F. and permitted to cool down slowly. While screws made from cold-rolled bars may sometimes be used without heat-treatment, those made from hot-rolled bars should never be used in the annealed condition.

SCREW-THREAD COMPARATOR. The Hartness screw-thread comparator is a projection type of apparatus designed to show the magnitude and kind of errors in screw threads. When the thread shadow is projected upon the standard tolerance chart, the relative positions of the shadow and chart not only show the resultant effect of lead errors, the pitch diameter, the finish and form of the thread, but also whether the tolerance is within the limits that are required in interchangeable manufacture.

SCREW THREADS. Different screw-thread forms and standards have been originated and adopted at various times, either because they were considered superior to other forms or because of the special requirements of screws used on a certain class of work. Some of the more important and desirable features of a screw thread are as follows: 1. The thread should be of such a shape that the tool for producing it can be easily made. 2. The cutting edges of the tool should not be so pointed or delicate that they are easily worn away by the cutting action. 3. It should be possible to test the diameter and form of the thread with a minimum of measuring and gaging. 4. The form should be such that a good bearing between a screw and nut may be obtained without unnecessary care and refinement in cutting and measuring. 5. The angles of the sides should be as acute as is consistent with the required strength, because the greater the angle, the greater the friction between the threads of a bolt and nut and also the greater the force tending to burst the nut.

Pitch. — The distance from the center (or top) of one thread to the center of the next thread, measured parallel to the axis of the screw is the pitch. This definition applies whether the screw has a single thread or is of the multiple-threaded form. The word " pitch " is frequently used to denote the number of threads per inch. For example, the expression " six-pitch screw " is used to indicate that the screw has six threads per inch. This usage of the word pitch is sometimes confusing and is not recommended.

Lead. — The distance that a thread advances in a single turn, or the distance that a nut would advance in an axial direction if turned one complete revolution is the lead. The lead and pitch of a single screw thread are equal; the lead of a double thread is twice the pitch; the lead of a triple thread is three times the pitch, and so on.

Pitch Diameter. — The pitch diameter, which is also known as the " angle diameter " and as the " effective diameter," is equivalent to the outside diameter minus the depth of one thread.

Root Diameter. — The minimum diameter of a screw or the diameter across the bottom or root of the thread, measured at right angles to the axis of the screw is the root diameter which is also known as the " core diameter."

Multiple Thread. — A multiple screw thread is formed of two or more single threads. For instance, a double thread is a multiple form having

two separate or single threads starting diametrically opposite or at points 180 degrees apart; a triple thread has three single threads starting at points 120 degrees apart; and a quadruple thread has four single threads starting at points 90 degrees apart. A multiple thread is used to increase the lead of a screw without weakening it by cutting a coarse single thread.

Standard Screw Thread. — A standard screw thread system conforms to an adopted standard in regard to the form or contour of the thread itself, and as to the pitch or number of threads per inch for given screw diameters.

Special Screw Thread. — A screw thread having either a modified form or a pitch which is either greater or less for a given screw diameter than the adopted standard is special. For information about different standard threads and thread forms, refer to name of thread or standard. See Acme Thread; American Standard Screw Thread; British Association Thread; British Standard Fine Screw Thread; French and International Thread; Harvey Grip Thread; Instrument Thread; Lamp Base and Socket Shell Threads; Löwenherz Thread; Pipe Thread; S. A. E. Standard Screw Thread; United States Standard Screw Thread; V-thread; Whitworth Standard Thread; Worm Thread.

SCRIBNER RULE. This is a rule employed for finding the board measure of logs, and is as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the log at the small end is measured.

SCROLL CHUCK. This type of chuck, used in lathes and similar types of turning machines, is one in which the jaws for clamping the work move together and remain at the same distance from the center, the jaws being moved radially by a spiral scroll which engages teeth on the back of the jaws. When the scroll is rotated, the jaws are moved in or out by the action of the spiral engaging the teeth on the jaws. The scroll is generally rotated by a bevel pinion meshing with bevel gear teeth cut on the back of the scroll.

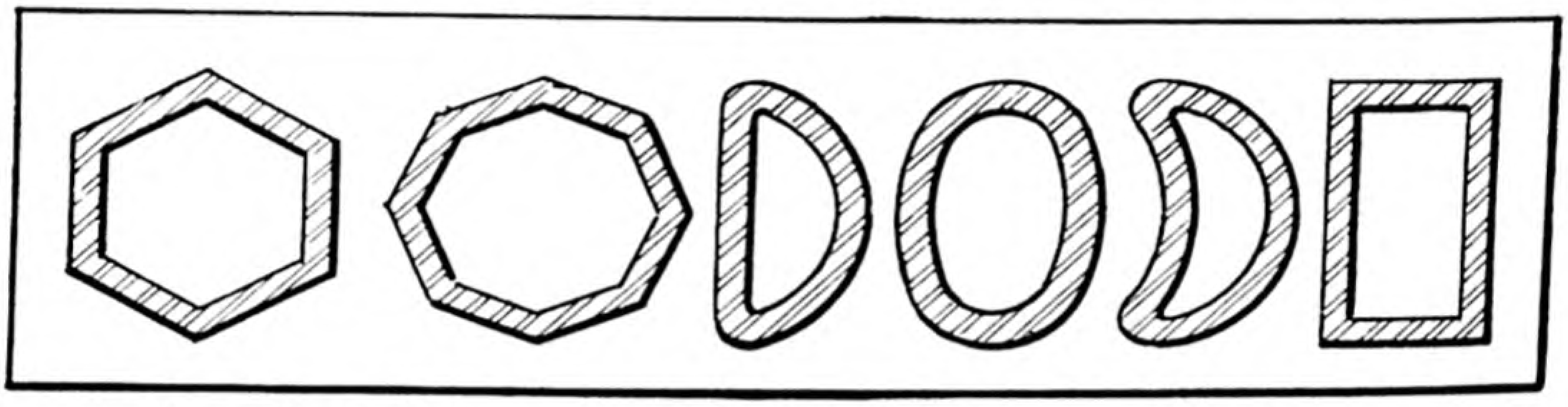
SCROLL LATHE. The scroll lathe is a special type designed for cutting spirals or scrolls used for operating the jaws of scroll chucks, and for work of a similar nature.

SEALE-TYPE WIRE ROPE. This rope is made from 6 strands of 19 wires each, and is also known as a "Seale hoisting rope." Sometimes this rope is made with a 6 by 12 construction, but this type is not recommended.

SEAMLESS BRASS AND COPPER TUBING. Seamless drawn brass and copper tubes are made in sizes varying from $\frac{1}{4}$ to 8 or 10 inches in diameter. The sizes do not correspond with any universal standard, but usually

increase by $\frac{1}{8}$-inch increments up to 3 inches, and by $\frac{1}{4}$-inch increments for larger diameters. The nominal diameter of tubes may be either the inside or outside diameter, brass and copper tubes being made to conform with both methods of measurement. The term "diameter," as applied to tubes, however, is generally understood to mean outside diameter. The thickness of the tube walls conforms to Birmingham wire gage.

SEAMLESS STEEL TUBING. Seamless tubing of circular cross-section is made in a large range of sizes, and there are also a number of special shapes (see illustration). There are four different processes of producing seamless steel tubes for pipes. 1. By piercing a solid billet or forc-



Some Special Shapes in which Seamless Tubes are Manufactured

ing a punch through its center while in a red-hot state, and then rolling or hot-drawing the hollow billet thus formed, in order to reduce the wall thickness and elongate it to secure the necessary tube lengths. 2. By drawing from a circular flat plate a shallow cup, which is elongated by a successive series of hot-drawing operations over a solid mandrel and through a series of dies, thus reducing the wall thickness and increasing the length. 3. By using a hollow cast-steel billet of tubular form which is reduced and elongated by rolling over a mandrel, or by hot-drawing operations similar to those referred to. 4. By piercing a solid billet which, by means of angular rolls, is given a high rotative speed and a slow advancing movement over a pointed mandrel, thus changing the billet from a solid to a tubular form. The Birmingham wire gage is used for seamless steel tubing, to gage the wall thickness (see Mannesmann Process).

SEASON CRACKS. In brass and other alloys, season cracks are defects due to molecular changes produced by mechanical deformation. These cracks become visible some time after rolling.

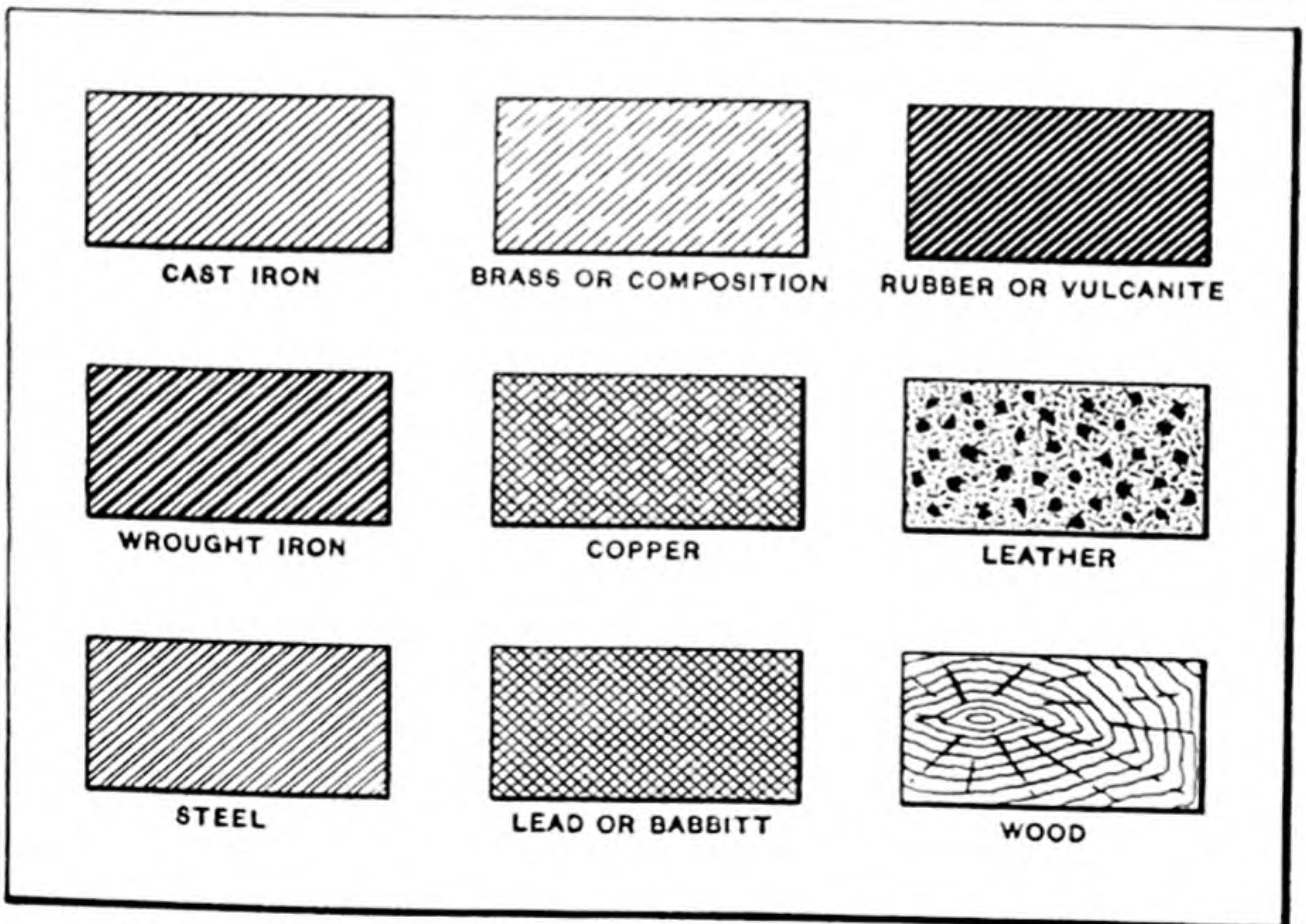
SEASONING STEEL AND CAST IRON. It is a well-known fact that hardened pieces of steel will undergo minute but measurable changes in form during a long period of time after the hardening has taken place. These changes are due to the internal stresses produced by the hardening process, which are slowly and gradually relieved. In order to eliminate slight inaccuracies which might result from these changes, steel used for

gages and other tools requiring a high degree of accuracy is allowed to season before it is finally ground and lapped to the finished dimensions. The time allowed for this seasoning varies considerably among different toolmakers and also depends upon the form of the work and the degree of accuracy which is necessary in the finished product. Some toolmakers rough-grind the hardened part quite close to the finished size and then allow it to season or "age" for three or four months, and, in some cases, a year or more. Castings will often change their shape slightly after being planed, especially if the planed surface represents a large proportion of the total surface. To prevent errors from such changes, castings are sometimes allowed to season for several weeks or months, after taking the roughing cuts and before finishing. A common method of avoiding the long seasoning period is to anneal the castings. Artificial seasoning is also applied to steel parts by subjecting them repeatedly to alternate heating and cooling.

SECANT OF ANGLE. See Functions of Angles.

SECTIONAL DIES. See Dies, Sectional Type.

SECTION LINES FOR DRAWINGS. Various kinds of metals and other materials are used in machine construction and, when sectional views



Cross-sections to Indicate Different Materials on Drawings

are made, it is convenient to have some standard method of cross-sectioning the different parts so as to indicate the kind of metal or material. Conventional sectionings adopted for this purpose are shown by the illustration. There is no universal standard but the sections shown are in common use and most of them have been standardized by general usage.

SECTION MODULUS. The section modulus of the cross-sectional area of a rod, bar, or beam is a value used in the calculation of the bending stresses in a beam subjected to load. The section modulus is equal to the moment of inertia of the cross-section, divided by the distance of the extreme fiber of the cross-section from the neutral axis. Generally the section modulus is denoted by Z; the moment of inertia, I; and the distance from the neutral axis to the extreme fiber, y. Then:

$$Z = \frac{I}{y}.$$

The polar section modulus, also known as the *section modulus of torsion,* equals, for circular sections, the polar moment of inertia divided by the distance from the center of gravity to the most remote fiber. This rule applies also with fair accuracy to sections that are nearly circular. For other cross-sections, the section modulus of torsion is not equal to the polar moment of inertia divided by the distance from the center of gravity to the most remote fiber. Methods have not yet been developed by means of which the section modulus of torsion may be calculated for cross-sections other than circular. Experiments have been made, however, and the section modulus of torsion has been determined in this manner for the most common cross-sections.

SEGER TEMPERATURE CONES. The fusible cone is a means for determining high temperatures in which the unequal fusibility of clay or earthenware blocks of varied composition is used. This means for determining temperatures is in use in pottery works and similar industries. The most well-known cones are known as the *Seger temperature cones,* also known as the *Sentinel temperature cones.* The Seger temperature cones are in the form of triangular pyramids (about 3 inches high), composed of metallic and mineral substances which fuse at certain temperatures. They are made in series, each successive cone having a fusing temperature that differs slightly from the one above or below in the scale; that is, if the series were placed in a furnace and the temperature gradually raised, one cone after another would melt as its melting point was reached. These cones are sometimes used in pairs to determine the minimum and maximum temperatures for a given process, one cone being selected for the lowest and another for the highest temperature required. Tests have shown that this method for determining temperatures is very trustworthy within 35 degrees F.

SEIZING The term seizing is used with reference to bearings to designate the condition when the shaft will not move freely, or at all, within the bearing, on account of lack of lubricant. In the absence of lubricant, the shaft and bearing are likely to scratch and score each other, and the increase

in friction suddenly produces a high temperature which causes an expansion of the shaft and of the interior parts of the bearing, so that the bearing box grips the shaft with an enormous pressure, or " seizes " the shaft.

SELECTIVE ASSEMBLY. Selective assembly consists of selecting by trial mating members of a mechanism that will give the desired fit at assembly, with little or no further machining or fitting. Companion parts made to the extreme limits are not supposed to interchange. For instance, a shaft or pin of maximum size may not assemble with a mating part of minimum size, although the maximum shaft and maximum hole and also the minimum shaft and hole must interchange. A good example of this selective method of assembling is found in the production of ball bearings. The balls are sorted into groups, according to their size, to facilitate the assembly of any bearing with balls of uniform size. Nearly every so-called " interchangeable " mechanism represents a combination of interchangeable and selective methods of quantity production.

SELENIUM. Selenium is a non-metallic chemical element. It possesses the peculiar quality or property of having its conductivity greatly increased by light. This property has been the basis of various electrical inventions, as for example, in various forms of apparatus for transmitting photographs by wire. Selenium has also been used in instruments for measuring the Roentgen rays used in therapeutic applications; in a form of Wheatstone bridge; in appliances intended to light and extinguish automatically the flame on gas buoys; in controlling street lights, electric signs, and moving pictures; in burglar alarms; and in controlling submarine boats. Selenium is used very largely in the making of glass, to which it gives a red color. It is also used to give a bright red color to enamels used on " enameled ware." The atomic weight of selenium is 79.2. Its specific gravity is 4.8, and it melts at a temperature of 217 degrees C. (423 degrees F.). Its specific heat varies from 0.072 to 0.115.

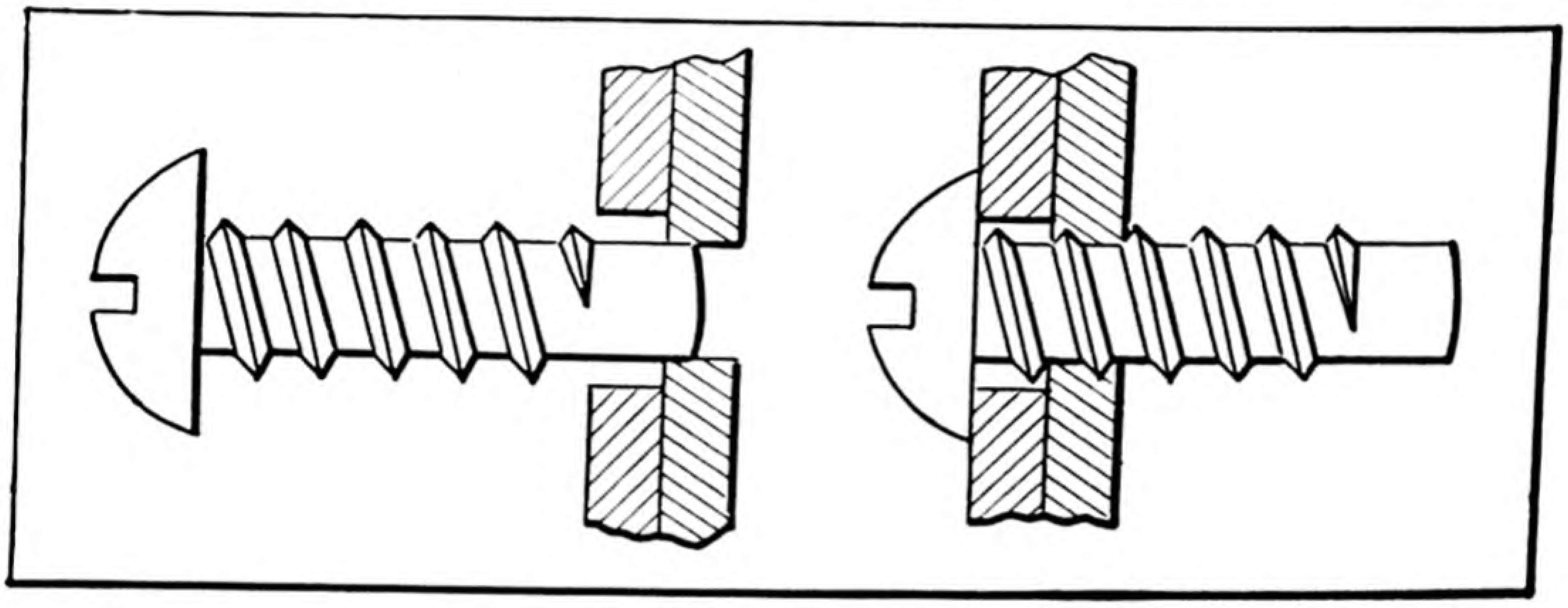
SELF-ALIGNING. This term is applied to machine members that are so mounted that they can adjust themselves within certain limits. The self-aligning principle, for example, is employed in certain bearings which are so mounted that the bearing can adjust itself to the alignment of the shaft

SELF-OPENING DIES. See Dies for Thread-cutting.

SELF-STARTER. In electric motor operation, a self-starter is an automatic starting device in which the starting box or controller is automatically operated or capable of being started by pushing a button or closing a switch at some remote point. Self-starters prevent the starting of motors too suddenly, and when combined with float switches, pressure regulators, and limit

switches, the motor may be started and stopped automatically at the proper time. These devices are most commonly used in connection with motor-driven pumps and air compressors.

SELF-TAPPING SCREW. The self-tapping screw is designed to cut its own thread in die- or sand-cast parts of gray iron and softer metals. The screw has a V-thread of fairly coarse pitch and a cylindrical pilot which



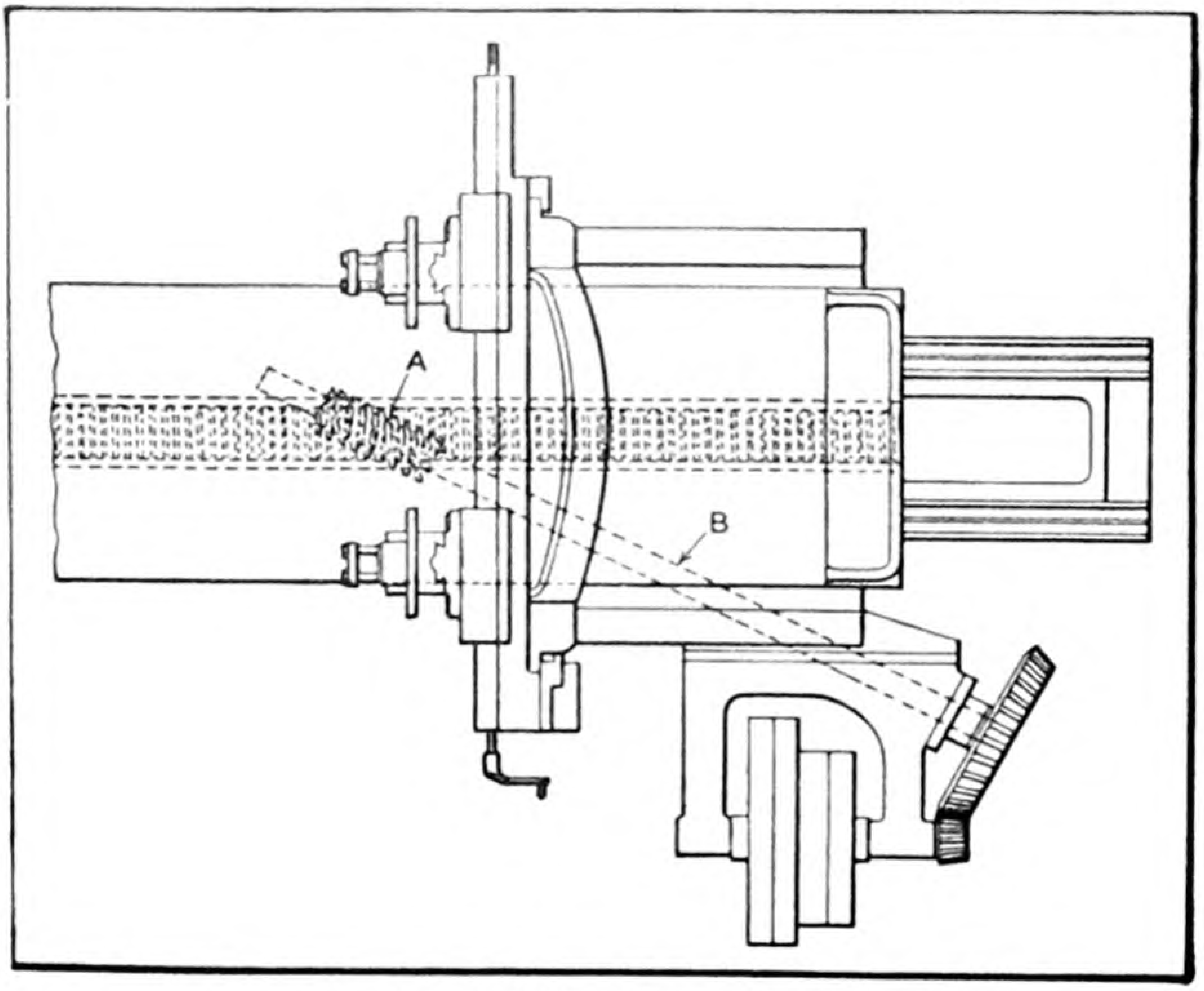
Self-tapping Screw

steadies the thread while it seats itself in the metal. See illustration. In using this screw, a hole is first drilled in the piece which would ordinarily be tapped, a few thousandths of an inch larger than the pilot, and the piece to be assembled is drilled sufficiently large to provide clearance for the threads of the screw. A common method of setting is to insert the pilot in the hole, make a few turns with a screwdriver, and then drive the screw into place. The entire screw is hardened and heat-treated so that the thread cuts into the metal.

SELLERS DRIVE FOR PLANERS. There are two general methods of driving a planer table. The most common form of drive is that in which the motion is transmitted from the driving shaft through spur gearing to a " bull-wheel " or spur gear, which meshes with a rack attached to the under side of the planer table. A planer driven in this way is known as a " spur-geared " type to distinguish it from the " spiral-geared " planer. With a spiral-gear drive (also known as the *Sellers drive*) the motion is transmitted from the belt pulleys through bevel gears to a shaft *B* which extends under the bed diagonally and carries a spiral pinion or worm *A*, which meshes with the table rack. See illustration on following page.

SELLERS MUFF COUPLING. This is a coupling consisting of two split sleeves, conical on the outside, forced together over the ends of the shafts by bolts. An outside sleeve, tapered to fit the conical bushings, is provided for closing up the split cones when the nuts on the bolts are tightened.

SELLERS SCREW THREAD. The Sellers screw thread, now known as the "United States standard thread," and also as the "American Standard" is the most commonly used screw thread in the United States. It was originated by William Sellers, of Philadelphia, and first proposed by him in a



Plan of Sellers Planer Drive

paper read before the Franklin Institute, in April, 1864. In 1868, it was adopted by the United States Navy and has since become the generally accepted standard screw thread in the United States.

SEMI-ANTHRACITE COAL. This is a kind of coal similar to, but not as hard as, regular anthracite, being less shiny and burning more rapidly. It contains from 85 to 90 per cent of carbon. The heating value varies from 14,500 to 15,500 B.T.U. per pound of combustible.

SEMI-AUTOMATIC MACHINE. This term is generally understood to describe a machine which performs a complete cycle of operations automatically, but which requires the attention of an operator each time a part is finished. Many machine tools which actually are semi-automatic are classed as "automatic" by their manufacturers.

SEMI-BITUMINOUS COAL. This coal is softer than anthracite and has a tendency to produce more smoke. It contains from 75 to 85 per cent of carbon and has a heating value of from 15,500 to 16,000 B.T.U.

per pound of combustible. It is one of the best coals for power plant purposes.

SEMI-HIGH-SPEED STEEL. The so-called semi-high-speed or intermediate steel was produced to meet the demand for a steel which could be used just as well as high-speed steel for certain purposes, and still be much lower in price. The quality of this steel, as far as cutting speed is concerned, is somewhere between ordinary carbon steel and the modern high-speed steel. It contains a much smaller percentage of tungsten than regular high-speed steels, and is sometimes called a low-tungsten steel.

SEMI-PRECISION GRINDING. Semi-precision grinding comprises operations which might be called in part machine grinding but which also depend upon some degree of hand manipulation. Typical instances are the slotting of granite and the surfacing and moulding of marble on planer type machines, the grinding of car wheels, the surfacing of manganese steel rails, the smoothing of street car rails, and the surface and internal grinding operations on manganese steel safe parts. The required limits of accuracy are usually not as close as in precision grinding and consequently the machines are not signed for extremely accurate work.

SEMI-STEEL. Semi-steel is made by adding mild steel to the pig iron and scrap in the cupola. The proportion of steel used varies from 15 per cent for light castings to 40 per cent for heavy castings. The resulting metal is a high-grade cast iron with fewer impurities and better physical structure than ordinary cast iron, and while this metal has practically no elongation or ductility, it is stronger than gray cast iron under transverse, tensile, compression, and impact tests, and is superior in elasticity, toughness, and resistance to shock and wear. When properly made, it is close-grained, homogeneous, and free from hard spots and blow-holes. It is greatly superior to gray iron for machinery, and takes on a finer polish, and permits the cutting of clean screw threads. It is especially good for such castings as cylinders, pistons, and gears, and other parts which are subjected to wear and friction. The 20 per cent mixture usually gives the desired results for machine tool work.

SEMI-VITRIFIED GRINDING WHEELS. The term "semi-vitrified" is sometimes applied to grinding wheels made by the silicate bonding process. See Silicate Bonding Process.

SENSITIVE DRILLING MACHINE. See Drilling Machines.

SENTINEL PYROMETERS. These consist of different metallic salts which are made up in mixtures that will melt at various specified temperatures ranging from 220 to 1330 degrees C. (428 to 2426 degrees F.). This

method of measuring temperatures is intended to replace more costly pyrometers and also for the purpose of checking the indications of pyrometers. See also Seger Temperature Cones.

SEPARATORS, CHIP, OIL, AND WORK. See Chip and Oil Separators; also Chip and Work Separators.

SEPARATORS, STEAM. See Steam Separators.

SEPTIVALENT. This term is used to indicate that an atom of one element will combine with seven atoms of another element.

SERIES CONNECTION. Electric batteries are connected in series when the positive or plus (+) terminal of one cell is connected to the negative or minus (−) terminal of the next cell. This connection increases the internal resistance, making it equal to the resistance of one cell multiplied by the number of cells. The electromotive force of the whole battery also equals that of one cell multiplied by the number of cells, but the amount of current of the whole battery remains the same as that of a single cell.

SERIES-WOUND GENERATOR. This type of generator has its field winding connected in series with its armature winding and the external circuit, as shown by the diagram. The whole current delivered by the machine flows through the field winding and the voltage varies with the load, increasing as the load increases, and *vice versa*. The usefulness of a series generator is, therefore, confined mainly to such services as require a fairly constant current, such as series arc-lamp circuits. The field winding is composed of heavy wire or strap in order to carry the large current without undue heating.

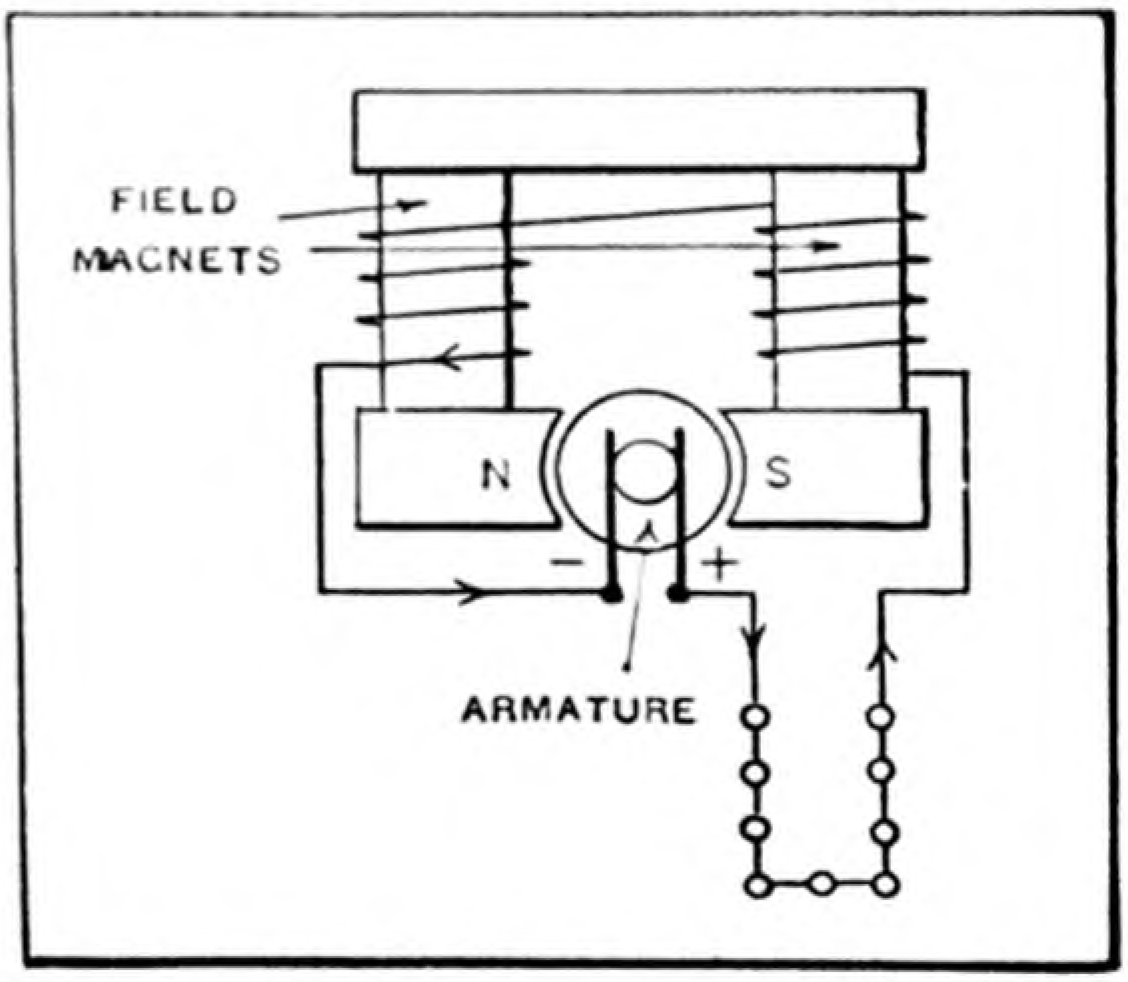


Diagram of Series-wound Generator

SERIES-WOUND MOTOR. The three types of direct-current motors are series-wound, shunt-wound, and compound-wound motors. The series-wound motor is one in which the field winding is in series with, or forms a direct continuation of, the armature circuit, so that all of the current that passes through the armature passes also through the fields. The amount of current drawn from the line by a motor depends upon the work, or horsepower, which the motor is developing. It therefore follows that in the series motor the strength of the fields will depend upon the load which is placed

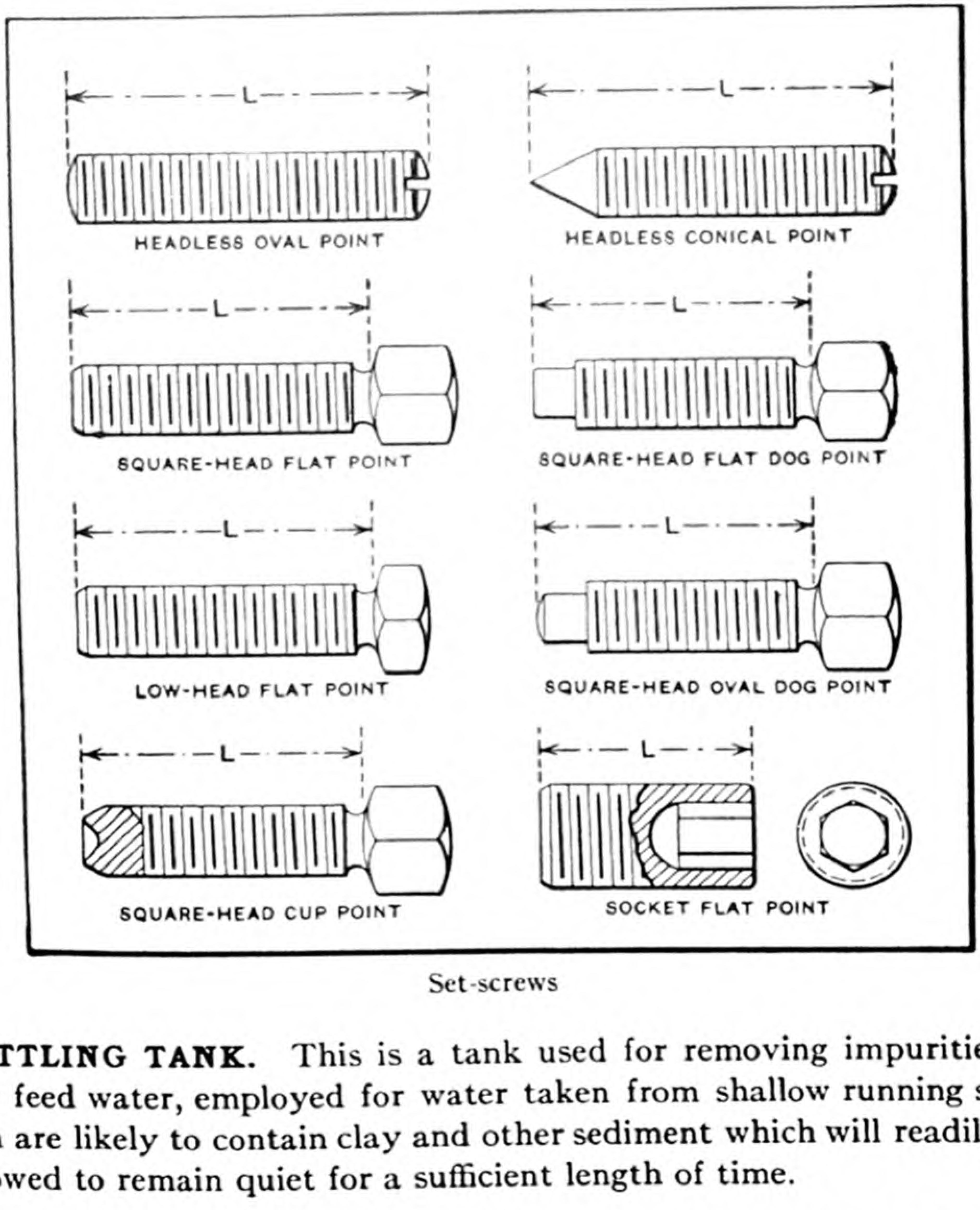
on the motor, and, as the speed of the motor depends inversely upon the field strength, the speed of the series motor will be inversely proportional to the load. Since the speed of a motor also depends upon the voltage that is impressed upon the armature, the speed of a series motor may be controlled by introducing resistance in series with the armature, and this is accomplished by means of a controller which is used also for starting the motor. The use of the controller enables the operator to start the motor slowly under light loads, and also prevents too great a flow of current when starting under heavy loads. The characteristics of the series motor are heavy starting torque and a speed dependent upon the load.

SERRATED FITTINGS. Serrated fittings are used quite widely in the automotive industry, often where square shafts formerly were used and for the purpose of preventing rotation of a member, the hub of which is fitted on a shaft. The serrations have an included angle of 80 degrees up to and including $\frac{5}{8}$-inch diameters, and of $82\frac{1}{2}$ degrees for larger sizes, and the included angle of the space between adjacent teeth is 90 degrees in all cases. There are flats at the top and root, practically the same as the U. S. form of thread. The serrations on the shaft mesh with those on the hub so that when the two parts are assembled there is a tight connection which resists any turning movement. The S. A. E. recommended practice covers serrated fittings of both straight and taper types. The latter has a taper on the outside diameter of $\frac{3}{4}$ inch per foot.

SET-SCREWS. The principal difference between a set-screw and a cap-screw is that the former bears on its point, whereas a cap-screw bears on its head. Set-screws are generally used to prevent relative motion between two machine parts, as, for example, when a set-screw passes through a tapped hole in the hub of a pulley and bears against a shaft which drives the pulley. Keys are preferable to set-screws for locking pulleys, gears, etc., to their shafts, and for similar work, although set-screws may serve the purpose when not subjected to heavy loads; they are used principally on the cheaper grades of machinery. Set-screws are not only used for locking parts together, but also as a means of obtaining slight adjustments, either to eliminate unnecessary play by means of gibs, or for changing the location of a tool or other part. On account of the danger caused by the projecting head of set-screws, hollow or "safety" set-screws are now used extensively. These have a square or hexagonal hole in the end for a wrench, instead of a projecting head. Different forms are shown on the following page.

SET-SCREWS, AMERICAN STANDARD. The American standard set-screws have nominal screw thread diameters ranging from $\frac{1}{4}$ inch to $1\frac{1}{2}$ inches, and the pitches are the same as the American coarse thread series

or the U. S. standard. The nominal widths across the flats are the same as the nominal screw thread diameters. For general use, set-screws having square heads are furnished. If there is a neck under the head its width must not exceed twice the pitch of the thread.



Set-screws

SETTLING TANK. This is a tank used for removing impurities from boiler feed water, employed for water taken from shallow running streams which are likely to contain clay and other sediment which will readily settle if allowed to remain quiet for a sufficient length of time.

SEWING MACHINE. The development and general introduction of the sewing machine was due largely to the work of Elias Howe, who secured a patent in 1846. In 1790 an English patent was granted to Thomas Saint for a crude form of sewing machine, and in 1826 a United States patent was granted to Lye, but the records were destroyed by fire in 1836. Various other patents were granted prior to the introduction of the Howe machine. Attempts were made to break the Howe patent, the claim being that his invention was anticipated by the experiments by Walter Hunt in 1834. The

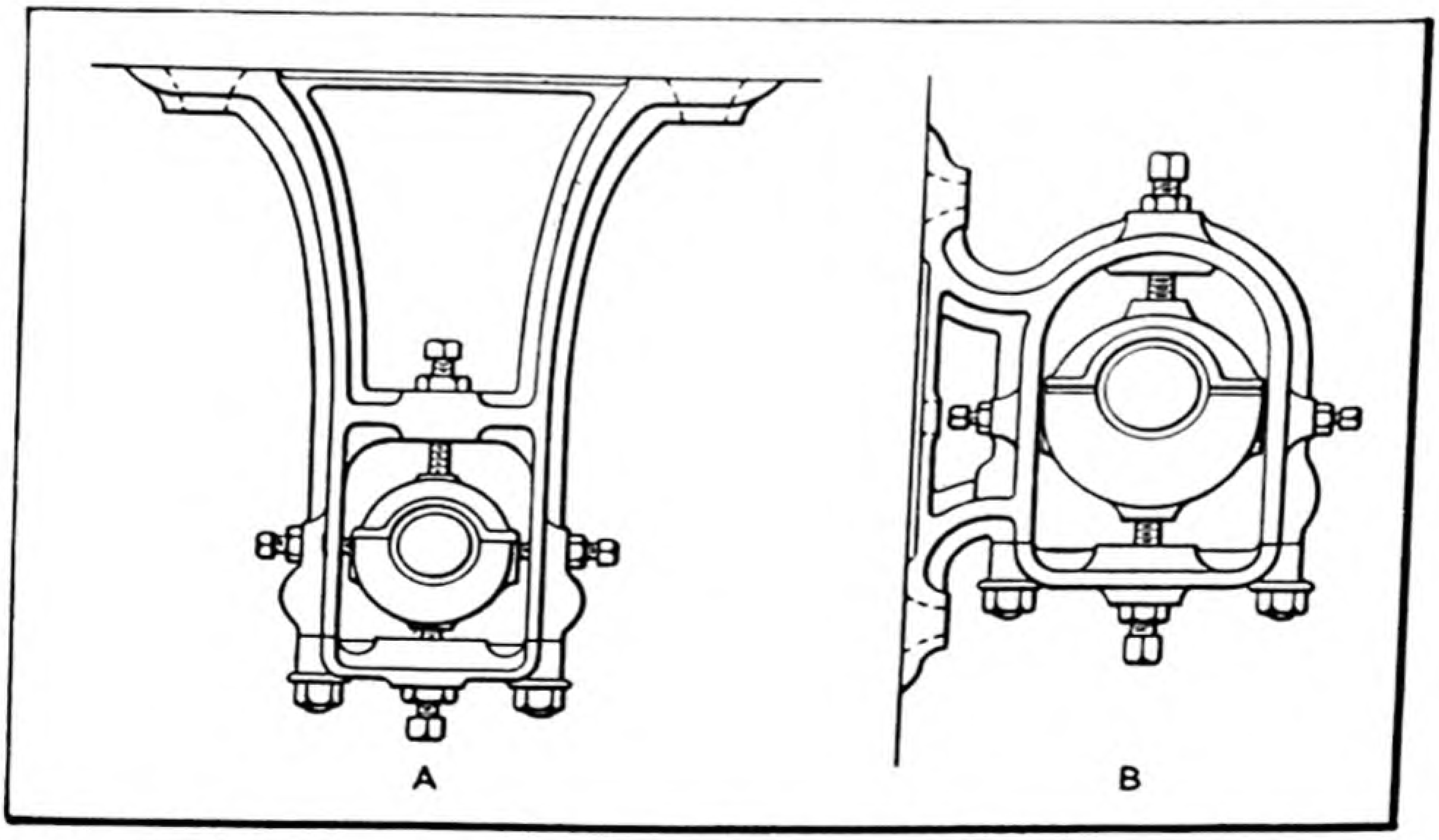
court upheld the Howe patent and infringers were obliged to pay him royalties. In 1852 a patent was granted to A. B. Wilson for inventing the rotary hook for carrying the bobbin to replace the reciprocating shuttle.

SEXIVALENT. This is a term used to indicate that an atom of one element will combine with six atoms of another element. It is also known as hexavalent.

SHAFT CLEANERS. A simple but effective method of keeping shafting clean is by the traversing-ring method. The ring is somewhat larger in diameter than the shaft, and it automatically travels to and fro between pulleys or bearings, the reversal being due to the change in the angular position of the ring when the leading side strikes a pulley hub or bearing at either end of its travel. As the ring is continually moving along the shaft, the latter is kept clean. These rings of the " homemade " variety are usually made of some material such as fiber or leather. A commercial type of ring is made of four semicircular stampings of heavy nickel-plated sheet zinc. The ring has a circular recess which is filled with felt for gathering and distributing any drops of oil that collect on the shaft, the object being to spread the oil thinly on the shaft so that it will oxidize and scale off.

SHAFT COUPLINGS. See Couplings for Shafts; also Flexible Couplings.

SHAFT HANGERS. A shaft hanger is composed of a frame and a bearing for supporting a shaft. The hanger shown at *A* in the accompanying



(A) Shaft Hanger for Ceiling. (B) Wall Bracket or Post Hanger

illustration is designed to be attached to the ceiling, whereas the form shown at *B* is applied to the side of a post. The latter design is usually known either as a *wall bracket* or a *post hanger.* Some hangers of the type shown at

A are made much shorter and heavier, especially when they are to support heavy shafting carrying main driving pulleys that transmit considerable power. Hangers of the suspended type shown at *A* are sometimes placed in an inverted position on the floor after turning over the bearing, and, when used in this way, they are usually known as *floor stands*, since they serve the same purpose as regular floor stands or pedestal bearings. The hanger bearings are also self-adjusting, so that they readily conform to the position of the shaft. The ball- and socket-bearing is extensively used for hangers.

SHAFTING. Shafting is used for transmitting power from one point to another and for supporting the means employed in power transmission, such as gears, pulleys, chain wheels, clutches, etc. The stresses to which shafts are subjected may be chiefly *torsional* stresses, chiefly *bending* stresses, or *combined torsional and bending* stresses. Shafts which simply transmit power from one point to another will, if supported by a sufficient number of bearings, be subjected chiefly to torsional stresses. Shafting of this type is found in the line-shafting in shops and factories. If, however, heavy pulleys and gears are supported by the shaft and especially if they are not located close to the bearings, the shaft may be subjected to severe bending stresses in addition to the torsional stresses due to the transmission of power. The axles of large water wheels are subjected chiefly to bending stresses and, for a short section only, to torsional stresses.

SHAFTING, COLD-DRAWN. See Cold-drawing.

SHAFTING DIAMETERS. The diameter of shafting for transmitting a given amount of power may be determined by the following formulas which are taken from the American Engineering Standards Committee's Code for the Design of Transmission Shafting. In these formulas:

D = outside diameter of shaft in inches;

K_m = combined shock and fatigue factor to be applied in every case to the computed bending moment (for rotating shafts, $K_m = 1.5$ for gradually applied or steady loads; 1.5 to 2 for suddenly applied loads and minor shocks only; 2 to 3 for suddenly applied loads and heavy shocks);

K_t = combined shock and fatigue factor to be applied in every case to the computed torsional moment (for rotating shafts and gradually applied or steady loads $K_t = 1$; for suddenly applied loads and minor shocks only $K_t = 1$ to 1.5; for suddenly applied loads and heavy shocks $K_t = 1.5$ to 3);

M = maximum bending moment in inch pounds;

N = revolutions per minute;

P = maximum number of horsepower to be transmitted by the shaft;

p_t = maximum shearing stress in pounds per square inch (the maximum shearing stress p_t, under combined load = 8000 pounds per square inch

for "commercial steel" shafting without allowance for keyways, and 6000 pounds per square inch with allowance for keyways. p_t = 30 per cent of the elastic limit in tension, but not more than 18 per cent of the ultimate tensile strength for shafting steel purchased under definite physical specifications);

S_s = maximum permissible torsional shearing stress in pounds per square inch (the values for S_s are the same as just given for p_t);

T = maximum torsional moment in inch pounds.

If a solid circular shaft is subjected to a pure torsional load

$$D = \sqrt[3]{\frac{321{,}000\ K_t P}{S_s N}}$$

If a solid circular shaft is subjected to combined torsion and bending

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{(K_m M)^2 + (K_t T)^2}}$$

$$D = \sqrt[3]{\frac{16}{\pi p_t}\sqrt{(K_m M)^2 + \left(\frac{396{,}000\ K_t P}{2\pi\ N}\right)^2}}$$

Distance between Bearings. — The bearings for shafting should be located close enough to limit the maximum deflection of the shaft to about 0.010 inch per foot of length. For average conditions the maximum distance between shaft bearings in feet may be determined by the following rules: For bare shafts, extract the cube root of the *square* of the shaft diameter in inches, and multiply this root by 6.3. For shafts carrying pulleys, etc., the cube root of the square of the shaft diameter in inches is multiplied by 5.2.

SHAFTING, FLEXIBLE. See Flexible Shafting.

SHAKING GRATE. This is a type of furnace grate made up of separate bars supported at the ends on rocker bearings. A lever for operating the grate is attached to one of these bearings. The rocker is so formed that alternate bars are moved backward and forward, thus producing a sliding movement which cleans the grate of ashes without the use of hand tools.

SHAKU. This is the Japanese unit of length, equal to 303.03 millimeters or 0.9942 foot.

SHALE OIL. See Oil Shale.

SHAO. This is a Chinese capacity measure, legalized in 1908, equal to 0.0104 liter or 0.0109 quart.

SHAPER CLASSIFICATION. The shaper, like the planer, is used principally for producing flat or plane surfaces, but it is intended for smaller work than is ordinarily done on a planer. The shaper is preferable to the planer for work within its capacity, because it is less cumbersome to handle and quicker in its movement. Shapers are classified in several different ways. For instance, the name applied to a given design may indicate the action of the machine when in operation, the type of driving mechanism, or other constructional features. The *crank shaper* is a very common design, and the name relates to the crank-driving mechanism for the ram. There are also *geared* or *rack shapers*, which are so named because the ram is driven through gearing and a rack attached to the ram. The crank-driven type is the one that is used principally. The details of different makes of the same type vary to some extent, but all shapers of the same class have certain essential features that are quite similar.

Friction Shaper. — The name " friction shaper " is sometimes applied to a geared shaper which is equipped with friction clutches for reversing the movement of the ram, instead of using shifting belts. There are two pulleys rotating in opposite directions, and these are alternately engaged by friction clutches which are operated by the tappets or dogs attached to the ram. These shapers avoid the shifting of the driving belts, and operate on the same principle as clutch-driven planers.

Traveling-head Shapers. — The traveling-head or traverse shaper differs radically from the standard type. The machine is equipped with a rather long box-shaped bed upon which the ram is mounted. This ram is carried by a saddle which feeds along the top of the bed when the shaper is in operation. The feeding movement of the saddle is at right angles to the traversing motion of the ram. Some shapers of this type are equipped with two shaper heads instead of one. A machine of the duplex type is very efficient for planing certain classes of work, especially if the parts are quite heavy or unwieldy, because the work remains stationary and it may be supported either by the adjustable tables or be placed upon the floor. Obviously the double-head machines may be used for planing separate parts, or, at times, the two heads may be used for planing each end of a long casting at one setting of the work.

Open-side Shaper. — A Richards or open-side shaper has a saddle which is traversed along the top of the bed by a screw, and the tool-slide is mounted upon a cross-rail located at right angles to the bed. When the shaper is in motion, the saddle and its attached head traverses to and fro along the bed, and the tool-slide is fed laterally, either by hand or automatically. The open-side shaper is superior to either the column or traverse shaper for many classes of work, especially when long and comparatively narrow surfaces need to be planed.

Draw-cut Shaper. — A shaper of the draw-cut type differs from the ordinary design in that the tool cuts when it is moving towards the column of the machine. In other words, the tool is pulled or drawn through the metal on the cutting stroke instead of being pushed. For this reason, the name " draw-cut " is applied to a shaper of this type. The planing tool is set with the cutting edge reversed. The object in designing a shaper to take a draw cut is to secure greater rigidity and, consequently, a higher degree of accuracy. The thrust of the cut is toward the column and this tends to relieve the cross-rail and other bearings from excessive strains, especially when taking deep cuts. As the ram is subjected to a tensile stress, it is claimed that vibrations are practically eliminated and that the tendency to vibrate diminishes as the depth of cut increases.

Vertical Shaper. — This machine resembles a slotter in many respects, but it is known as a vertical shaper and is adapted for classes of work that are done on horizontal shapers and regular slotting machines. The work-table of this shaper can be given a transverse, longitudinal, or rotary movement. The ram which carries the planing or slotting tool moves vertically, while the table is fed either by hand or automatically in whatever direction is required. The ram can be placed perpendicular to the table or at an angle for slotting dies, etc. It is mounted in an independent bearing, the upper part of which is pivoted, so that both the bearing and ram can be adjusted to an angular position, which is indicated by degree graduations. Work can often be completed at one setting by a shaper of this type, as it may be used for machining either straight, curved, or irregular surfaces.

SHAPER, GEAR. See Gear Shaper.

SHAPER INVENTION. The shaper for planing metals, was invented by James Nasmyth who was one of Maudslay's pupils. Maudslay perceived that Nasmyth was an extraordinarily skillful workman, and he not only employed him, but took him into his own office as his personal assistant. Nasmyth stayed for several years or until Maudslay's death, in 1831, when he started in business for himself. He became one of the foremost tool builders in England, and invented the shaper in 1836 which was long known as Nasmyth's " steam arm." The " quick return " was first applied to the shaper by Whitworth.

SHARP SAND. Sharp sand is lake or seashore sand, river sand, bank sand, or silica or fire sand, used in the making of cores for the foundry. The sand is mixed in varying proportions with fine grades of molding sand.

SHAVING DIES. Dies of this class are sometimes used for finishing the edges of comparatively thick blanks which have been cut out in a regular blanking die. A blanking die used for cutting heavy stock must have a

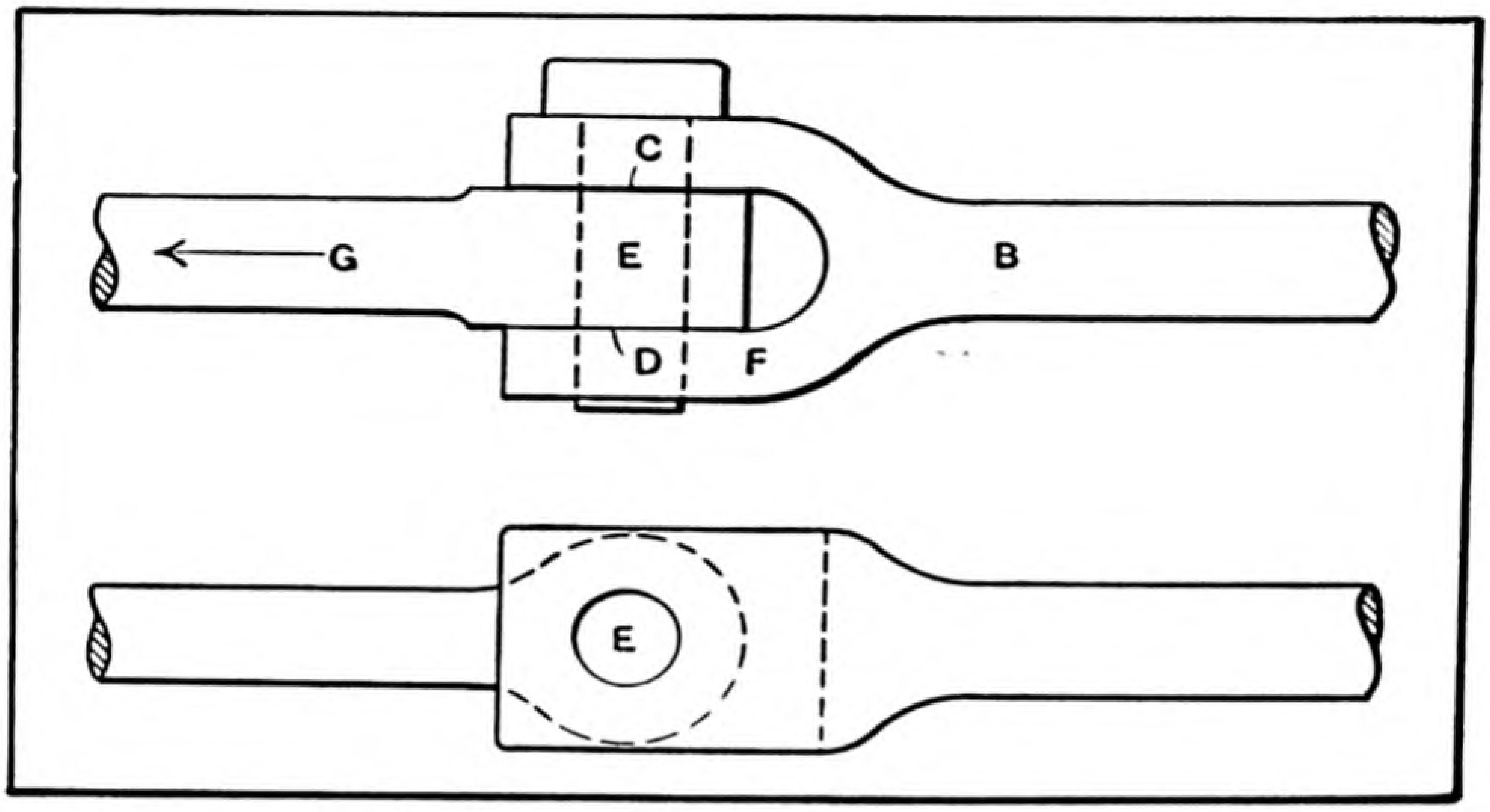
certain amount of clearance between the punch and die opening, the amount depending upon the thickness and kind of material. As the result of this clearance (which lessens the danger of breaking the punch and reduces the pressure required for the punching operation), the edges of thick blanks are somewhat rough and also tapering. To secure smooth, square edges, *shaving dies* are used in some cases.

SHAVING TOOLS. When forming work of irregular contour, in the automatic screw machine it is common practice to use a shaving tool which is operated tangentially to the work and passes either under it or over it as conditions may require. It is customary to place the shaving tool on the rear cross-slide, so that the shaving operation can be accomplished at the same time as the turret operations, when the spindle is running forward. The chief use of this tool is for finishing work after it has been rough-formed with a circular form or other external cutting tool.

SHEARING MACHINES. The shears or shearing machines used in boiler shops, shipyards, machine shops, etc., for splitting or trimming steel plates and for cutting off bars and structural material, are made both in hand- and power-operated types, and in many different designs. The machines used for shearing are, in many cases, also adapted to punching operations by replacing the shear blades with one or more punches and dies. There are also combination designs having a punch on one side and a shear on the other. A shearing machine of the ordinary type is equipped with one fixed blade and one movable blade which receives motion from a mechanism designed to give a powerful cutting movement. The blades intended for different classes of work vary in form and the motion of the blade relative to the material being sheared also varies on different types of machines. One of the simplest and oldest types of power-driven shearing machines is known either as a *lever shear*, an *alligator shear*, or a *crocodile shear*. It is adapted to the shearing of scrap, or for cutting billets, muck bars, and sheet bars in rolling mills, and for similar work. Another design of shearing machine is known as a *vertical* type. The upper or movable shear, instead of being attached to a pivoted lever, is bolted to a slide which is given a vertical reciprocating motion. The vertical design is often preferred to the horizontal machine where economy of floor space is important. Some shears have a vertical reciprocating slide which is operated by a lever connected by a pitman with a crankshaft at the rear.

SHEARING STRESSES. The pin E (see diagram) is subjected to a shearing stress. Parts G and B are held together by the pin and tend to shear it off at C and D. The areas resisting the shearing action are equal to the cross-sectional areas of the pin at these points. The general formula for shear is: Load = cross-sectional area × working stress. The permissible

working stress for shear is assumed as four-fifths or five-sixths of the permissible working stress in tension. If a pin is subjected to shear so that two surfaces, as at C and D, must fail by shearing before breakage takes place, the areas of both surfaces must be taken into consideration when calculating the strength. The pin is then said to be in *double shear.* If



Pin Subjected to Shearing Stresses

the lower part F of connecting-rod B were removed, so that member G were connected with B by a pin subjected to shear at C only, the pin would be said to be in *single shear.*

SHEARING TEST. This test is made by cutting through a specimen and recording the load required. The specimen to be tested may be subjected to either " single " or " double " shear.

SHEAR OF PUNCHES AND DIES. When the cutting face of a die is inclined each way from the center, or is made hollow, it is said to have *shear.* The cutting faces of dies are given shear for the same reason that the teeth of some milling cutters are made helical or spiral, in that the shear makes it possible to cut the blank from the sheet with less expenditure of power and, therefore, reduces the strain on the punch and die. Whether a die should be given shear or not depends upon the thickness of the stock to be cut and, in some cases, upon the power of the press available. When shear is required it is advisable sometimes to leave the face of the die flat and give shear to the punch instead. In general, the shear is given to the punch when the stock around the hole is the desired product and the material removed by the punch is the scrap. The face of the die is sheared when the blank or that part which is cut out by the punch is the product.

SHEARS, SQUARING. See Squaring Shears.

SHEAR STEEL. This steel is usually in the form of bars, and is made from blister steel, by shearing it into short lengths, arranging in piles, and welding these piles by rolling or hammering at a welding heat. If this process of shearing, etc., is repeated, the product is called "double-shear steel." Shear steel is made principally in England and is used for articles of cutlery, etc.

SHEAR THEORY, MAXIMUM. See under Stress Theories.

SHEDDING. In lead storage batteries, shedding is the condition when the plates lose or shed their active material. Shedding is due either to imperfect formation or application of the material, to undue expansion or contraction, or to the rapid release of gas bubbles, when charging is done at high rates or carried too far.

SHEET. A finished rolling mill product known as a "sheet" is produced by rolling sheet bars in sheet mills. The term "sheet" is applied to material having a thickness less than No. 12 gage. (The United States Government limits the thickness of sheets to No. 10 U. S. standard gage.) Ordinarily, sheet mills do not roll stock thinner than No. 30 gage.

SHEET BAR. A "sheet bar" is a semi-finished rolling mill product that is flat and less than 2 inches thick, and from 6 to 12 inches wide.

SHEET IRON. Sheet iron may be either black or galvanized. Galvanized sheets should be thoroughly and evenly coated, of bright appearance, and free from blisters, ragged edges, or other defects. The zinc coating should not flake or peel off when scraped with a knife, or when the sheet is bent sharply to right angles. The sheet should never be re-rolled after leaving the galvanizing bath, except for the purpose of straightening. The zinc used for galvanizing should contain at least 98 per cent pure zinc. The minimum zinc coating per square foot for galvanized plates should vary from 1.35 to 1.65 ounce, the smaller value being used for the thinnest sheets and the higher value for the heavier sheets.

SHEET METAL GAGES. In the United States, a universally adopted standard gage for sheet and plate iron and steel, has not been used, there being a number of different gages. The U. S. standard gage for sheets and plate was legalized by Act of Congress, March 3, 1893, as a standard gage to be used by the Custom House departments for sheet iron and steel. This gage was adopted by about forty-five sheet and tin plate manufacturers. In addition to the U. S. standard gage, the Birmingham gage, the American or Brown & Sharpe gage, and the standard decimal gage have also been used for iron and steel, as well as for copper and brass, and, in addition, a special gage for tin plate, another for zinc, and still another for what is known as

American "Russia-iron." The *standard decimal gage* for sheet metal was adopted in 1895 by the American Society of Mechanical Engineers and the American Railway Master Mechanics' Association. In this gage, the number for each thickness is the number of thousandths of an inch of the thickness of the metal, so that a sheet 0.016 inch thick is No. 16 in the decimal gage. A number of large manufacturing concerns have discontinued the use of gage numbers entirely in referring to wire, sheet metal, etc., and give the dimension in decimals of an inch. The tariff act of 1913 provides for the measurement of steel strips "by gage," but as the particular gage was not designated in the tariff act, the Treasury Department in 1914 authorized the use of the American (B. & S.) wire gage. Prior to this the Birmingham wire gage had been employed. The Treasury Department also directed that the measurement of sheets and plates be in decimals of an inch instead of using the standard gage. See Gages for Sheet Metals.

SHEET-METAL TESTING. Tensile strength tests are unsatisfactory for determining the quality of thin sheet metal that is to be worked in power presses, etc., because of two reasons: in the first place, such tests do not yield reliable data for very thin sheets; second, the quality of metal which is to be worked by drawing, stamping, folding, etc., is dependent upon ductility and similar properties rather than upon tensile strength. A machine has been developed for determining what is known as the Erichsen value, *i.e.*, the depth in millimeters before the metal is torn, of an impression made by forcing the sheet metal through a die. See Ericksen Value.

SHEET STEEL. Sheet steel is made from soft steel containing a low percentage of carbon. The United States standard plate gage sizes most generally considered under the heading of "sheet steel" are those from No. 10 (0.141 inch thick) down to No. 30 (0.013 inch thick). Sheets corresponding to the various gage numbers between these limits are made in widths of 24, 26, 28, and 30 inches, and in lengths of 72, 84, 96, and 120 inches. Nos. 10 to 16, inclusive, are also made in widths of 36, 40, 42, and 48 inches, and in lengths of 144 inches, and Nos. 17 to 24, inclusive, are also made in sizes 36 inches in width and 144 inches long. See Cold-rolled Sheet Steel.

SHELLAC, PATTERN. See Pattern Varnish or Shellac.

SHELLING. Shelling is the rupturing of the surface or shell surrounding the inner core of bar stock, which sometimes occurs when cold-drawing large sizes.

SHELL REAMERS. Shell reamers have a hole through the center by means of which they are mounted on arbors, or detachable shanks. By making the reamers in this manner, one arbor can be used for a number of sizes. The negative front rake on shell reamers should not be more than

about 3 degrees. The corners at the end of the fluted shell reamer are slightly rounded.

SHENG. This is a Chinese capacity measure, legalized in 1908, equal to 1.035 liter or 1.094 quart.

SHERARDIZING PROCESS. The sherardizing process was originated in England by Sherard Cowper-Coles about 1904. The process is applicable not only in all cases where hot or cold galvanizing can be used, but in numberless other cases where they cannot. Briefly, the process consists in packing the articles to be covered with the zinc coating into a closed drum, box, or other suitable receptacle in contact with the ordinary zinc dust of commerce. The receptacle is then put into an oven and gradually heated to the required temperature of about from 500 to 700 degrees F., for a period of four or five hours. At the same time, the retorts are turned intermittently so as to give the zinc dust access to all parts of the work. After holding this heat for several hours, the exact time depending upon the thickness of the coating desired, the drums are withdrawn from the furnace and allowed to cool down to a temperature convenient for handling, when its contents are dumped upon a screen, which allows the zinc dust to fall freely into the chamber below, from which it can be drawn for use again. The articles are found to be evenly coated with pure zinc. A sherardized surface is light gray in color, and the finish imparted is a fine matted surface resembling that obtained by sand-blasting.

The preparation of the surfaces of articles to be sherardized is important, if good results are to be assured. The presence of rust or scale greatly interferes with the sherardizing action. To prevent the articles from rusting after cleaning with acid by pickling they should be thoroughly neutralized by placing them in a boiling solution of cyanide, allowing 5 to 6 pounds of cyanide crystals to 100 gallons of water. If the articles are cleaned by sand-blasting there is no danger of rust If sand-blasting cannot be done for some reason then correct pickling and after treatment are necessary before placing the articles in the sherardizing drum. A good pickling bath for cleaning iron or steel castings consists of 10 per cent each of hydrofluoric and sulphuric acid with 80 per cent water. The acids should be separately diluted before being added to the bath. A diluted sulphuric acid bath is sometimes used as a pickling solution for iron castings. After pickling with hydrofluoric or sulphuric acid, the castings should be washed in water, followed by an immersion in an alkaline (soda) solution to neutralize any remaining traces of acid. After being thoroughly cleaned the castings should be immediately transferred to a tank of clean water so as to preserve them from oxidation. When the sherardizing equipment is ready the cleansed castings may be put into the drums wet, as they come directly from the water tank.

SHI. This is a Japanese measure of weight, equal to 0.000375 gram or 0.0058 grain.

SHIMM. In mechanical work a shimm is a thin sheet of material (usually brass, steel or some other metal) which is sometimes applied between parts to provide convenient means of making adjustment either to compensate for wear or for other reasons. When a bearing, for example, is in the form of two half sections, a shimm may be placed between these sections to provide later for adjustment either by inserting a thinner shimm or by reducing the thickness of the one originally used. By thus reducing the thickness, the bearing sections are located closer together and play due to wear may be eliminated. The laminated shimm is an improved form consisting of layers of metal which can be peeled off to obtain the desired thickness. This laminated form provides a quick and accurate method of obtaining adjustments by the shimm method.

SHIPPING MEASURE. For measuring entire internal capacity of a vessel: 1 register ton = 100 cubic feet. For measurement of cargo: 1 U. S. shipping ton = 40 cubic feet = 32.143 U. S. bushels = 31.16 Imperial bushels. 1 British shipping ton = 42 cubic feet = 33.75 U. S. bushels = 32.72 Imperial bushels.

SHOCK. In mechanics, shock is the sudden application of a load to a structural or machine member. Machine parts subjected to shock must be stronger in proportion to the load which they carry than machine parts which are subjected to a steady load or to a load which gradually increases or diminishes.

SHORE SCLEROSCOPE. See Scleroscope.

SHORT-CIRCUIT. A short-circuit is an electrical circuit that does not pass through electrical apparatus as normally intended, but along a shorter path as in cases of defected insulation; thus a short-circuit usually represents an accidental condition.

SHORT-LAP BELT. A short-lap belt is a leather belt made entirely from that part of the hide which comes from the back of the animal and in which the strips are not long enough to include any portion of the neck stock. This is the best kind of belting.

SHORT-LEAD ATTACHMENT. In cutting screw threads or helical grooves of long lead in an engine lathe, it is well known that the gearing is subjected to severe stresses because of the high ratio of gearing required to traverse the carriage a distance per revolution of the spindle, equal to the lead of the groove being cut. The same difficulty is encountered in milling helical grooves, but in the case of the milling machine it is the short leads

that impose severe stresses upon the change-gears. This is due to the fact that the milling of a short lead requires a comparatively rapid rotation of the work, since the latter must make one revolution while the table is traversing a distance equal to the lead. Attachments are made for both lathes and milling machines which are designed to overcome this difficulty.

One design of short-lead attachment for a milling machine is arranged to drive the worm-shaft of the spiral head from the main spindle of the machine, instead of from the slowly revolving feed-screw, as is done ordinarily. The feed-screw is disengaged from the power feed mechanism while using the short-lead attachment. With this arrangement, the rotation of the work is independent of the feed-screw, and the latter rotates with and is driven from the work-spindle.

SHOVEL-NOSE TOOL. A shovel-nose tool is a tool, used in a lathe, boring mill, or similar type of machine tool, which is wider at the point than at the base where it joins the shank, and which has a broad, flat cutting surface. It commonly is fused for boring and facing pockets or recesses in the face or side of a casting or other machine part.

SHRINKAGE ALLOWANCE FOR PATTERNS. See Pattern Shrinkage Allowance.

SHRINKAGE CRACKS. In castings, shrinkage cracks are due to the excessive shrinkage of the metal upon solidification, caused either by a poor arrangement of the mold, poor design of the casting, or, in certain alloys, to the extreme brittleness at a temperature just below that of solidification.

SHRINKAGE FITS. A cylindrical part which is to be held in position by a shrinkage fit is first turned a few thousandths of an inch larger than the hole in which it is to fit; the diameter of the latter is then increased by heating, and after the part is inserted, the heated outer member is cooled, causing it to grip the pin or shaft with tremendous pressure.

General practice seems to favor a smaller allowance for shrinkage fits than for forced fits, although in many shops the allowances are practically the same in each case, and for some classes of work, shrinkage allowances exceed those for forced fits. In any case, the shrinkage allowance varies to a great extent with the form and construction of the part which has to be shrunk into place. The thickness or amount of metal around the hole is the most important factor. The way in which the metal is distributed also has an influence on the results. Whether parts are to be assembled by forced or shrinkage fits depends upon conditions. For example, to press a steel tire over its wheel center, without heating, would ordinarily be a rather awkward and difficult job. On the other hand, pins, etc., are easily and quickly forced into place with a hydraulic press and there is the additional advantage of

knowing the exact pressure required in assembling, whereas there is more or less uncertainty connected with a shrinkage fit, unless the stresses are calculated.

Tests to determine the difference in the quality of shrinkage and forced fits showed that the resistance of a shrinkage fit to slippage was, for an axial pull, 3.66 times greater than that of a forced fit, and, in rotation or torsion, 3.2 times greater. In each comparative test, the dimensions and allowances were the same. The most important point to consider when calculating shrinkage fits is the stress in the hub at the bore, which depends chiefly upon the shrinkage allowance. If the allowance is excessive, the elastic limit of the material will be exceeded and permanent set will occur, or, in extreme cases, the ultimate strength of the metal will be exceeded and the hub will burst. See also Forced Fits.

SHRINKAGE RULE. Except in unusual cases, a pattern-maker does not figure shrinkage by adding it to dimensions measured by the standard rule, but uses a shrinkage rule instead. These rules can be procured in all standard shrinkages; they are oversize the amount of shrinkage per foot. A two-foot rule, having an allowance equivalent to $\frac{3}{16}$ inch shrinkage per foot, will measure $24\frac{3}{8}$ inches by the standard rule. These shrinkage rules do not differ in appearance from standard rules. They are graduated on the four edges in sixteenths, eighths, tenths, and twelfths.

SHRINKAGE STRAINS. Shrinkage strains are produced in castings by the solidification of some parts of it sooner than others. In a casting, the thinner sections will solidify first in the mold; when the heavier sections solidify, they often create stresses in the other sections. One way to minimize these stresses is to arrange the thickness in the various parts of the casting as far as possible so that the entire casting will solidify at the same time.

SHRINK-HOLES IN CASTINGS. A shrink-hole is a cavity caused by the shrinking away of the metal in cooling. This defect is most likely to occur in those parts of a casting which are excessively thick. If practicable, avoid sudden changes in the thickness of a section.

SHROUDED GEARS. The teeth of some cast gears are joined together at the ends by a flange or wall of metal in order to strengthen the teeth. Gear teeth which are reinforced in this way are said to be shrouded. If this shroud or supporting wall only extends to one-half of the height of the teeth, instead of to the tops, the gear is known as a semi-shrouded form.

SHUNT TRIP. A shunt trip is an arrangement for tripping circuit-breakers. The shunt trip has its coil normally disconnected from the circuit and trips as soon as the coil is connected in the circuit. It is generally used

to trip a circuit-breaker from a distant point by the closing of a switch or similar device.

SHUNT-WOUND GENERATOR. In the shunt-wound generator the field winding is connected to the brushes of the machine and is thus in parallel with the armature winding, forming a shunt to the same, as shown by the diagram. This shunt is a comparatively fine wire of high resistance, thus limiting the field current to a small percentage of the total current, although the number of turns is proportionately higher. The voltage of such a generator is maximum at no load and, unless regulated, decreases as the load increases. Regulation is accomplished by inserting an adjustable resistance or rheostat in the field circuit; if resistance is cut out, the field current is increased and also the voltage of the machine, and *vice versa*. Modern shunt-wound generators with commutating poles have a very close inherent regulation, so that a very small change is required in the position of the rheostat between no load and full load.

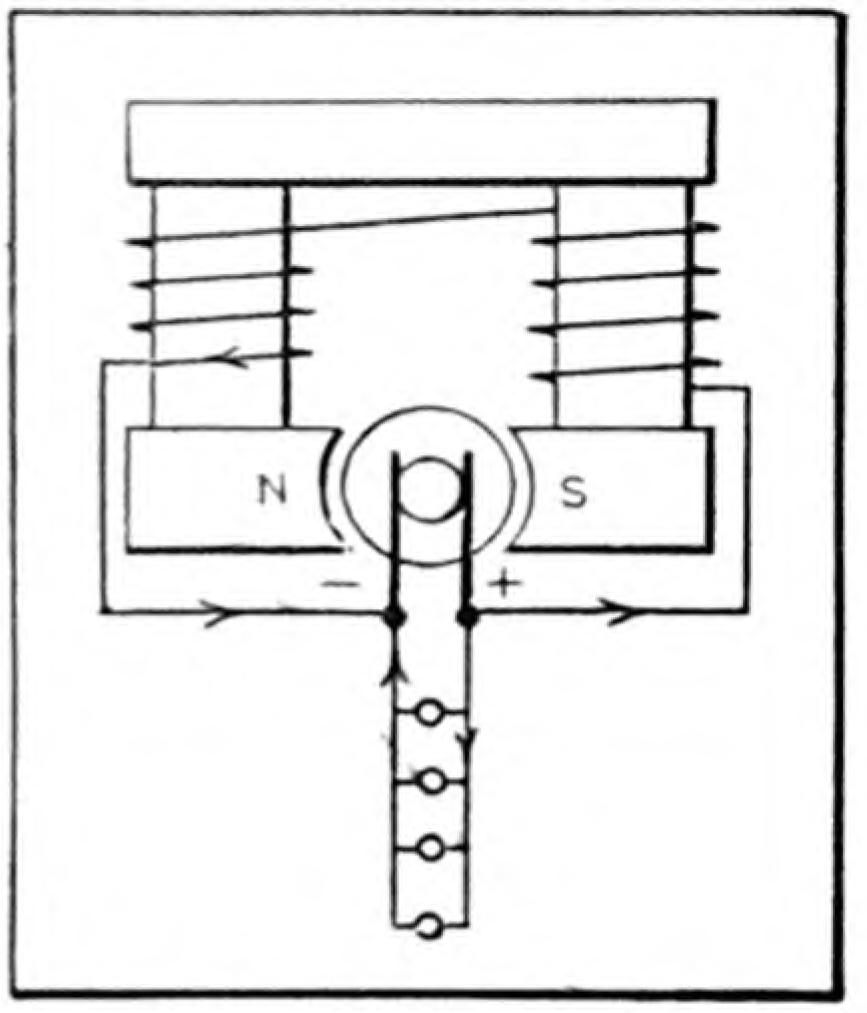


Diagram of Shunt-wound Generator

SHUNT-WOUND MOTOR. The shunt-wound motor is one in which the field winding is connected across the main lines, or is said to be in shunt with the armature circuit. The amount of current passing through the fields is inversely proportional to their resistance, and, except in the case of the variable-speed motor which will be treated later, remains practically constant under all conditions of load. This results in a constant-speed motor the output of which, in horsepower, is dependent upon the current, in amperes, which passes through the armature. The characteristic of the shunt-wound motor is approximately constant speed under all conditions of load.

SHUT HEIGHT OF PRESS. The term "shut height" as applied to power presses, indicates the die space when the slide is at the bottom of its stroke and the slide connection has been adjusted upward as far as possible. The "shut height" is the distance from the lower face of the slide, either to the top of the bed or to the top of the bolster plate, there being two methods of determining it; hence, this term should always be accompanied by a definition explaining its meaning. According to one press manufacturer, the safest plan is to define "shut height" as the distance from the top of the bolster to the bottom of the slide, with the stroke down and the adjustment up, because most dies are mounted on bolster plates of standard thickness, and a misunderstanding which results in providing too much die space is less

serious than having insufficient die space. It is believed that the expression " shut height " was applied first to dies rather than to presses, the shut height of a die being the distance from the bottom of the lower section to the top of the upper section or punch, excluding the shank, and measured when the punch or upper section is in the lowest working position.

SIDE-FIRED FURNACES. The side-fired type of furnace, with various modifications, has been used extensively for the annealing of brass, copper, and German silver. It is very commonly built with grates for the use of coal and wood. If for the former fuel, a steam blower is often installed in the ash-pit wall. For the use of oil fuel, suitable openings are made in the side walls and the grates are covered with two or more courses of firebrick. By adjusting the air supply to give a long flame, it is possible to obtain a fairly uniform temperature across a heating chamber from 5 to 7 feet wide. Chambers 8 feet wide have given satisfactory service for some purposes. The conducting of the waste gases under the heating chamber floor will assist in heating the bottom of the work and increase the efficiency of the furnace.

SIDE MILLING CUTTERS. A side milling cutter is provided with teeth on both sides as well as on the periphery of the cylindrical surface. Side milling cutters are used for cutting grooves or slots, as well as for many other operations. They are often used in conjunction with other forms of cutters for milling special shapes in a single operation.

SIDE-TOOLS. Side-tools are used in lathes for facing the ends of shafts, collars, etc. A right side-tool operates on the right-hand end or side of a shaft or collar, whereas the left side-tool is used on the opposite side. Side-tools are also bent to the right or left because the cutting edge of a straight tool cannot always be located properly for facing certain surfaces. See also Lathe Tools, Right- and Left-hand.

SIEMENS-MARTIN PROCESS. The open-hearth process of making steel has been designated by various terms. In connection with the original open-hearth process (acid) developed by C. W. Siemens, pig iron was used without scrap, and ore was added to oxidize the impurities; hence, the name " pig and ore process." The addition of scrap to molten pig iron without ore was a development of the Martin brothers; consequently, the origin of the terms " Siemens-Martin process," "Martin process," and " pig and scrap process." In the United States the term " open-hearth process " is generally used, the name being based upon the type of furnace employed.

SILENT CHAIN TRANSMISSION. The silent or " inverted-tooth " type of driving chain has the following distinguishing features: The chain passes over the face of the wheel like a belt and the wheel teeth do not pro-

ject through it; the chain engages the wheel by means of teeth extending across the full width of the under side, with the exception of those chains having a central guide link; the chain teeth and wheel teeth are of such a shape that as the chain pitch increases through wear at the joints, the chain shifts outward upon the teeth, thus engaging the wheel on a pitch circle of increasing diameter; the result of this action is that the pitch of the wheel teeth increases at the same rate as the chain pitch. Another distinguishing feature of the silent chain is that the power is transmitted by and to all the teeth in the arc of contact, irrespective of the increasing pitch due to elongation. The links have no sliding action either on or off the teeth, which results in a smooth and practically noiseless action, the chain being originally designed for the transmission of power at higher speeds than are suitable for roller chains.

The efficiency of the silent chain itself may be as high as 99 per cent, and for the complete drive, from 96 to 97 per cent, under favorable conditions; from 94 to 96 per cent can be secured with well-designed drives under average conditions. While the name " silent chain " is derived from the fact that the operation is practically noiseless, the term is not applicable to other types which may run silently, but is used to designate the inverted-tooth form of chain. The distinguishing feature of different makes of silent chain is in the joint, the other characteristics being practically the same, except for variations in regard to accuracy and manufacturing methods.

SILICA. Silica is amorphous silicon dioxide (SiO_2) and constitutes the greatest part of sand and sandy rocks. It occurs naturally as quartz and tridymite, which, when colored, forms some of the gem stones. When prepared artificially, it is a fine, white, tasteless, odorless powder that is soluble only in hydrofluoric acid, and is fused by alkaline carbonates. Silica, or quartz, crushed and graded to various sizes, is used in making sandpaper and sand belts, for frosting glass with sand-blast apparatus, and for other abrasive purposes. It may also be fused in the electric furnace to produce laboratory crucibles.

SILICATE BONDING PROCESS. Silicate grinding wheels derive their name from the fact that silicate of soda or water glass is the principal ingredient used in the bond. These wheels are also sometimes referred to as *semi-vitrified* wheels. Ordinarily, they cut smoothly and with comparatively little heat, and for grinding operations requiring the lowest wheel wear, compatible with cool cutting, silicate wheels are often used. Their grade is also dependable and much larger wheels can be made by this bonding process than by the vitrified process. Some of the grinding operations for which silicate wheels have been found to be especially adapted are as follows: For grinding high-speed steel machine shop tools, such as reamers, milling cut-

ters, etc.; for hand-grinding lathe and planer tools; for surface grinding with machines of the vertical ring-wheel type; and for operations requiring dish-shaped wheels and cool cutting. These wheels are unequaled for wet grinding on hardened steel and for wet tool grinding. They are easily recognized by their light gray color.

SILICON BRONZE. Silicon bronze is an alloy made from varying proportions of copper and silicon, often containing small percentages of zinc and tin. This alloy has been used to a considerable extent for wires conducting an electric current, such as trolley, telephone. and telegraph wires. It is made by heating fluosilicate of potash, granulated glass, chloride of sodium and calcium, and carbonate of soda and lime in a plumbago crucible. This mixture, after reaction takes place, is added to molten bronze. Silicon-bronze wire has a high electric conductivity, amounting to from 40 to 98 per cent of that of copper wire, or four times greater than that of iron. Its tensile strength is also high, varying from 55,000 to 110,000 pounds per square inch. The electrical conductivity decreases as the tensile strength increases, so that wire having a conductivity of 95 per cent of that of pure copper has a tensile strength of 55,000 pounds per square inch, while wire having a conductivity of 40 per cent of that of pure copper has a strength of about 100,000 pounds per square inch. The wire resists oxidation to a considerable extent, and has been largely used for telegraph wires. Ordinary drawn and annealed copper wire has a strength of only from 30,000 to 40,000 pounds per square inch.

SILICON CARBIDE. The artificial abrasive produced from a coke and sand mixture is known as silicon carbide. The electric resistance furnace is used in its production. Wheels made from this abrasive are adapted for grinding materials of low tensile strength, such as soft brasses and bronzes, cast and chilled iron, aluminum, copper, marble, granite, leather, and other non-metallic substances.

SILUNDUM. Silundum is a trade name for silicified carbon obtained by heating carbon rods in silicon vapor in an electric furnace. Being a form of carborundum, it has the same properties; it is very hard and acid-proof and resists high temperatures. It can be heated in the air to 1600 degrees C. (2912 degrees F.) without oxidation. Silundum rods have about three times the resistance of carbon; they are used in electrical heating and cooking devices, and are made in round, flat, and square bars or tubes and in the form of grids.

SILVER. Silver is the most malleable and ductile of all metals, with the exception of gold. Its specific gravity varies from 10.51 to 10.62. The average value is 10.53, making the weight per cubic inch 0.38 pound. Silver

melts at a temperature of 961 degrees C. (1762 degrees F.). Its specific heat is about 0.056. Its coefficient of linear expansion per unit length, per degree F., equals 0.0000108. Its thermal conductivity is higher than that of any other metal, and is generally taken as the standard with which the heat conductivity of other materials is compared, that of silver being assumed as 100. As compared with copper, its heat conductivity is in the ratio of 100 to 74, and as compared with gold, in the ratio of 100 to 54. Silver is also the most perfect conductor of electricity, and is assumed as the standard with which all other conductors are compared, the conductivity of silver being assumed as 100. As compared with copper, its conductivity for electricity is in the ratio of 100 to 75, and as compared with gold, 100 to 73. In hardness, silver is superior to gold, but it is not as hard as copper. Fifteen grains of silver have been drawn into a wire nearly 600 feet long, and silver leaves have been beaten out to a thickness of only 0.00001 inch.

SILVER-BRONZE, MANGANESE. See Manganese Silver-bronze.

SILVER FINISH ON BRASS. A method of silvering that is applicable to such work as gage or clock dials, etc., consists of grinding together in a mortar 1 ounce of very dry chloride of silver; 2 ounces of cream of tartar; and 3 ounces of common salt. Then add enough water to make it of the desired consistency and rub it on the work with a soft cloth. This will give brass or bronze surfaces a dead-white thin silver coating, but it will tarnish and wear if not given a coat of lacquer. The ordinary silver lacquers that can be applied cold are the best. The mixture, as it leaves the mortar before adding the water, can be kept a long time if put in very dark-colored bottles, but, if left where it will be attacked by light, it will decompose

SILVER-PLATING. Silver is not deposited in smooth coherent layers from all solutions. Silver deposits from a silver-nitrate solution, for example, is in a loose crystalline form, entirely useless for plating. From cyanide baths, which are universally used for silver-plating, the deposit is smooth, coherent, and of a milk-white color, which, on polishing, takes the appearance of ordinary silver. The bath may be made as follows: potassium cyanide, 98 per cent, from $6\frac{1}{3}$ to 7 ounces; potassium silver cyanide, crystallized, $KAg(Cu)_2$, $17\frac{1}{2}$ ounces; distilled water, 10 quarts. The current density is from 1 to 4.2 amperes per square foot, at about 1 volt, and pure silver anodes are used. Silver is deposited only on surfaces of copper or of copper alloys; if other metals are to be silver-plated, a layer of copper or brass is first produced, and the silver is deposited on this. After this surface has been cleaned and pickled, it is amalgamated by immersing in a quickening solution, which is made as follows: potassium mercury cyanide, 0.9 ounce; potassium cyanide, 0.9 ounce; water, 1 quart. The object remains in this solution only long enough

to acquire a uniform white coating of mercury, when it is rinsed in clean water and placed in the silver-plating bath. In order to make the silver adhere more firmly, the object is plated first for a few seconds in a striking solution with a relatively high current density, and then finished in the bath just given. The striking solution used by a prominent manufacturer of silverware, is as follows: Potassium cyanide, 6 ounces; potassium silver cyanide, 0.9 ounce; water, 1 gallon. It is advantageous to agitate the solution by keeping the articles in motion while in the bath. See also Electroplating.

SILVER SOLDER. Silver solders are made in strip, sheet, and granular form, and in a number of different grades of fusibility. The melting points of silver solders vary between 1250 and 1500 degrees F. One of the best silver solders used is made of 61 per cent silver, 29 per cent copper, and 10 per cent zinc. Many alloys of low silver content are used, in which the silver ranges from 5 to 50 per cent. Silver solder is especially suitable for jointing monel metal, nickel, and stainless steel, since it gives the necessary whiteness to the seam or joint, whereas with ordinary brazing solder, a red or yellow color is noticeable at the joint.

For successful silver soldering, it is essential that the parts be maintained throughout the operation in close, firm contact. This insures the ready flow of the solder, and results in a neat and exceedingly strong joint. Silver soldering is usually done by means of an air-acetylene blowpipe, or atmospheric gas blowpipe, and powdered borax is generally used as a flux. Borax, in paste form, is the cleanest and most convenient flux. The paste is produced by moistening the borax in clean water. The flux can be applied to the parts to be jointed with a small brush.

The work should be heated gradually at first, so as to harden the borax flux; then heating should be continued with a clean flame until a red heat is reached, at which temperature the solder will run and penetrate interstices which ordinary hard solders would fail to fill. As soon as the joint has been completed, the source of heat should be removed and the work quickly plunged in clean cold water. This method of procedure disintegrates the flux and scale, which if left to cool slowly, would set in a very hard vitreous film that is extremely difficult to remove.

SILVER-WHITE ALLOY. A white metal alloy of high luster, capable of taking a brilliant polish and closely resembling silver in appearance, consists of 70 per cent copper, 15 per cent nickel, 9 per cent zinc, 4.3 per cent tin, and 1.7 per cent lead. The alloy is made as follows: The nickel is first melted with a flux of silica, and half of the copper is added gradually and mixed, after which the remainder of copper is added. The zinc is then quickly plunged beneath the surface of the molten metal which is stirred rapidly until the whole is melted. The lead and tin are added last while liquid.

The metal is stirred and brought to a temperature of about 1700 degrees F., after which it is poured into ingot molds.

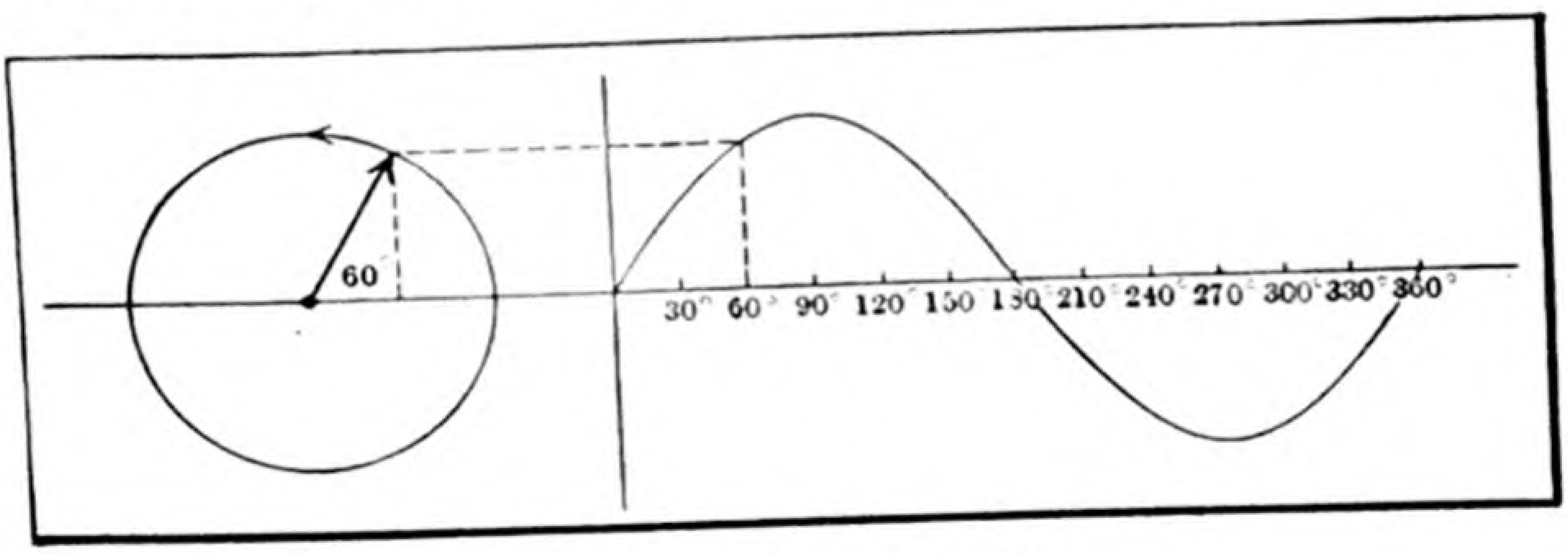
SINE, ARC. See Arc Sine and Tangent.

SINE-BAR. The sine-bar, or *sine-protractor*, as it is sometimes called, is used either for measuring angles accurately or for locating work to a given angle. It consists of an accurate straightedge to which are attached two hardened and ground plugs. These plugs must be of the same diameter, and the distance between their centers should, preferably, be an even dimension, to facilitate calculations. When the sine-bar is to be set to a given angle for locating some part with reference to it, it is first set approximately. The sine of the required angle is then found and this sine is multiplied by the distance between the plug centers, to obtain the vertical distance between the plug centers, for that particular angle. The bar is then adjusted until this vertical distance coincides with the dimension found.

SINE LAW. See Law of Sines and Cosines.

SINE OF ANGLE. See Functions of Angles.

SINE WAVE. The sine wave (see diagram) may be defined as follows: If, as the spoke of a wheel revolves at a uniform rate around its hub, a curve is plotted on rectangular coördinates to show the relation between the angle



Vector and Sine Wave

the spoke makes with the origin, and the distance from the end of the spoke to a horizontal line drawn through the hub, the curve so drawn will be a *sine curve*. The spoke is called the *vector* and the height of the peak of the wave is equal to the length of the vector. One revolution of the vector forms a *cycle*, which includes two "alternations" and two "half-waves," one positive and one negative. In order to specify a sine wave, it is sufficient to know the value of the vector and the number of cycles that take place per second. An alternating current not only reverses in direction, but changes to maximum and minimum values and in direction of flow according to a definite cycle, which is usually a close approximation of a *sine wave;*

and, in dealing mathematically with alternating current, the cycle is assumed to be exactly a sine wave.

SINGLE-CONDUCTOR CABLE. This term is applied to an electrical conductor consisting of several strands not insulated from one another and suitable for carrying a single electric current.

SINGLE-POLE CIRCUIT-BREAKER. This type of circuit-breaker is used on direct-current railway circuits, where only one side of the circuit is brought to the switchboard.

SINGLE-PURPOSE MACHINE TOOLS. Many modern developments in the machine tool field pertain to designs that are more or less special. These machines range from "manufacturing types," resembling simplified standard designs of unusual rigidity and power, to "single purpose" machines built specifically for one operation. The semi-single-purpose type of machine is now regarded favorably, particularly for certain operations in the automotive industry. Such machines, while designed for a given part, are arranged to accommodate different sizes, the idea, in some instances, being to care for possible future changes in the design of a car or other product.

SIPHON BAROMETER. This is an instrument used for measuring the pressure of the atmosphere. It consists of a tube bent to a U-shape, one leg of the tube being about 36 inches long and hermetically sealed at its upper end where a vacuum is formed; the remainder of the tube contains mercury. The pressure of the atmosphere is indicated by the difference between the levels of the mercury in the two vertical legs of the U-tube. See also Barometer.

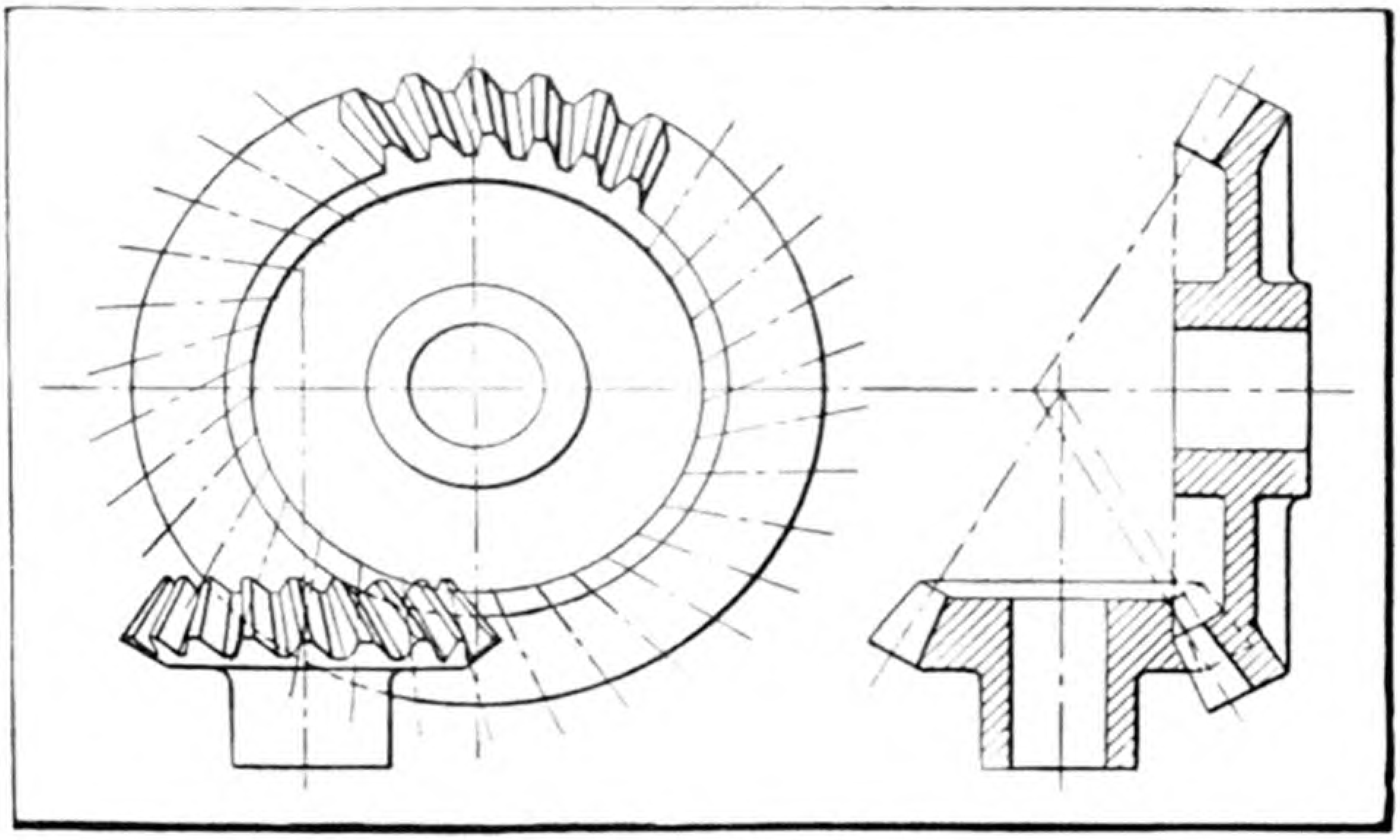
SIPHON-BAROMETRIC CONDENSER. A barometric condenser is not equipped with an air pump but is connected with a discharge or tail pipe having an elevation of at least 34 feet above the surface of the hot-well. See Condenser.

SIPHON CUP. An oil cup having a wick which feeds lubricant continually to bearings by capillary action, is called a siphon cup.

SIZE-INDICATING GRINDING MACHINE. See Internal Grinding Machine, Size-indicating.

SKELP PLATES. The plates used in the manufacture of welded tubes and pipes are known as "skelp plates." These plates are rolled to such a width and thickness as will produce the desired diameter and strength of tubing. The edges are generally sheared for large sizes of pipe. Grooved skelp plates are rolled in mills having grooves cut into the rolls equal to the width of the plates.

SKEW BEVEL GEARS. Skew bevel gears may be used to connect two shafts which are not parallel and which are not in the same plane, and which, in addition, are so close together that spiral or worm gearing cannot be satisfactorily applied. Skew bevel gears have straight teeth which bear on each other along a straight line, but these teeth do not converge or point to a common center, as in the case of ordinary bevel gears; they are, instead, inclined



Skew Bevel Gears

to a plane passing through the axis of the gear (see illustration). A plane through the center of the tooth intersects the axis of the gear instead of passing through the axis as in ordinary bevel gearing.

SKIN-DRIED MOLDS. Green sand molds are said to be skin-dried when only the interior surface is dried. This may be done to avoid the use of dry sand or loam molds, or, in some cases, because the sand used requires drying in order to withstand the heat and "wash" of the metal. Molds that are to be skin-dried should have a facing sand that will withstand drying like a dry sand mold. The facing sand is backed with ordinary heap or floor sand.

SKIRT BOARD. A skirt board is a guide or board placed at the side of belt conveyor installations for preventing the material carried from falling out or spilling on the side.

SKULL CRACKER. A drop weight, used for breaking scrap castings, etc., into smaller pieces, is called a skull cracker. The spherical weight or ball is hoisted above the scrap and released by pulling a rope attached to the releasing latch or trigger.

SLAB. A "slab," according to the usage of the term in rolling mill practice, is flat and at least 2 inches thick and 12 inches wide.

SLABBING MACHINES. Horizontal milling machines of the planer type are often termed *slabbing machines*, especially when they are used chiefly for the milling of plane surfaces or for "slabbing" operations. Some manufacturers classify their slabbing machines as vertical or horizontal types, depending upon the position of the milling spindle or spindles, as the case may be. Others do not distinguish between the horizontal and the vertical types, but apply the name "slabbing machine" regardless of the position of the spindles. Rotary planers are sometimes called slabbing machines.

SLACK OF SCREENINGS. This is a finely pulverized coal which passes through a screen of $\frac{3}{16}$ inch mesh. This coal is often known as culm or culm coal and is frequently used in power plants.

SLAG CEMENT. A cement made by mixing granulated basic blast furnace slag and hydrated lime and then grinding the mixture. It is the same as Pozzuolanic cement.

SLAVIANOFF WELDING PROCESS. This electric welding process is a modification of the Bernardos arc process. Instead of using a carbon electrode, the electrode is of the same material as the metal to be welded, this change being made in order to prevent the hard welds which sometimes result with the Bernardos or Zerener processes, owing, principally, to the transfer of carbon from the electrode to the weld.

SLEDGE HAMMERS. The weight of sledge hammers varies according to the size and weight of the work for which they are used; some hammers only weigh 8 pounds, while others weigh 20 pounds or over. Smaller hammers of the same pattern, weighing less than 8 pounds, are called *quarter hammers*, and those used for the very lightest work, generally are made with a ball-peen like a hand hammer and are called *backing hammers*.

SLENDERNESS RATIO. See Ratio of Slenderness.

SLIDE-REST DEVELOPMENT. Devices for clamping metal cutting tools in a fixed position were employed comparatively early, but the first record of the slide-rest dates from 1772. Complete drawings and details of an excellent slide-rest were given in that year in a French encyclopedia. As early as in 1741, Hindley, a York clockmaker, produced a screw-cutting lathe with change-gears. This was a very small machine used in the clockmaking trade only. None of these early developments, however, have had any commercial importance, or, apparently, any direct influence on the development of machine tools. The real foundation of modern machine tools was laid about 1794 by Maudslay who developed the first slide-rest to receive

general practical application. Apparently Maudslay was not acquainted with the French slide-rests that had been in use previous to 1772, and, on account of the development that has followed the design of slide-rest made by him, the credit for the development of the slide-rest is generally given to Henry Maudslay, of London. Up to about the time of Maudslay's design of slide-rest, the best lathes in existence were substantially like the present pattern-makers, speed lathe, having a light headstock and tailstock, and an adjustable rest for a hand tool, which was used for metal as well as for wood. Any refinement that had been made in previous years belonged apparently only to very small machines used by clockmakers, who in those days seemed to have the monopoly in mechanical ingenuity. About 1800, Maudslay provided his lathe with lead-screw and change-gears, in addition to a slide-rest, and from then onward the development of the modern machine tool has been continuous and rapid.

SLIDE-REST OF COMPOUND TYPE. The compound type of slide-rest for lathes has angular adjustment in a horizontal plane and it enables a tool to be fed at right angles to the lathe bed, parallel with it, or at any intermediate angle. There is a lower slide which is adjustable at right angles to the ways of the bed, and an upper slide which may be set in any angular position for boring taper holes, turning taper surfaces, etc. The circular base of the upper slide is graduated in degrees.

SLIDE-RULE. The slide-rule is an instrument by the aid of which various calculations may be made mechanically, with greater ease and rapidity than by ordinary arithmetical means, and usually with a sufficient degree of accuracy to meet all practical requirements. It is used most extensively for performing multiplication and division of numbers, but it may be used for finding powers, roots, logarithms, and trigonometric functions, and for various other purposes.

SLIDE VALVE. The simplest form of valve for steam engines is that known as the *plain slide valve.* Fig. 1 shows a longitudinal section of a slide valve with the ports, bridges, etc. The valve is shown in mid-position in order that certain points relating to it may be more easily understood. The valve V consists of a hollow casting, with ends projecting beyond the ports as shown; the lower face is smoothly finished and fitted to the valve seat AB. In operation, it slides back and forth, opening and closing the ports which connect the steam chest with the cylinder. Steam is admitted to the cylinder when either port CD or DC is opened, and is released when the ports are brought into communication with the exhaust port MN. This is accomplished by the movement of the valve, which brings one of the cylinder ports and the exhaust port both under the hollow arch K. The portions DM

and *ND* of the valve-seat are called the bridges. It will be seen that the portions *OI* and *IO* are wider than the ports which they cover. This extra width is called the *lap*, *OC* being the *outside lap* and *DI* the *inside* or *exhaust lap*. The object of the outside lap is that the steam may be shut off after

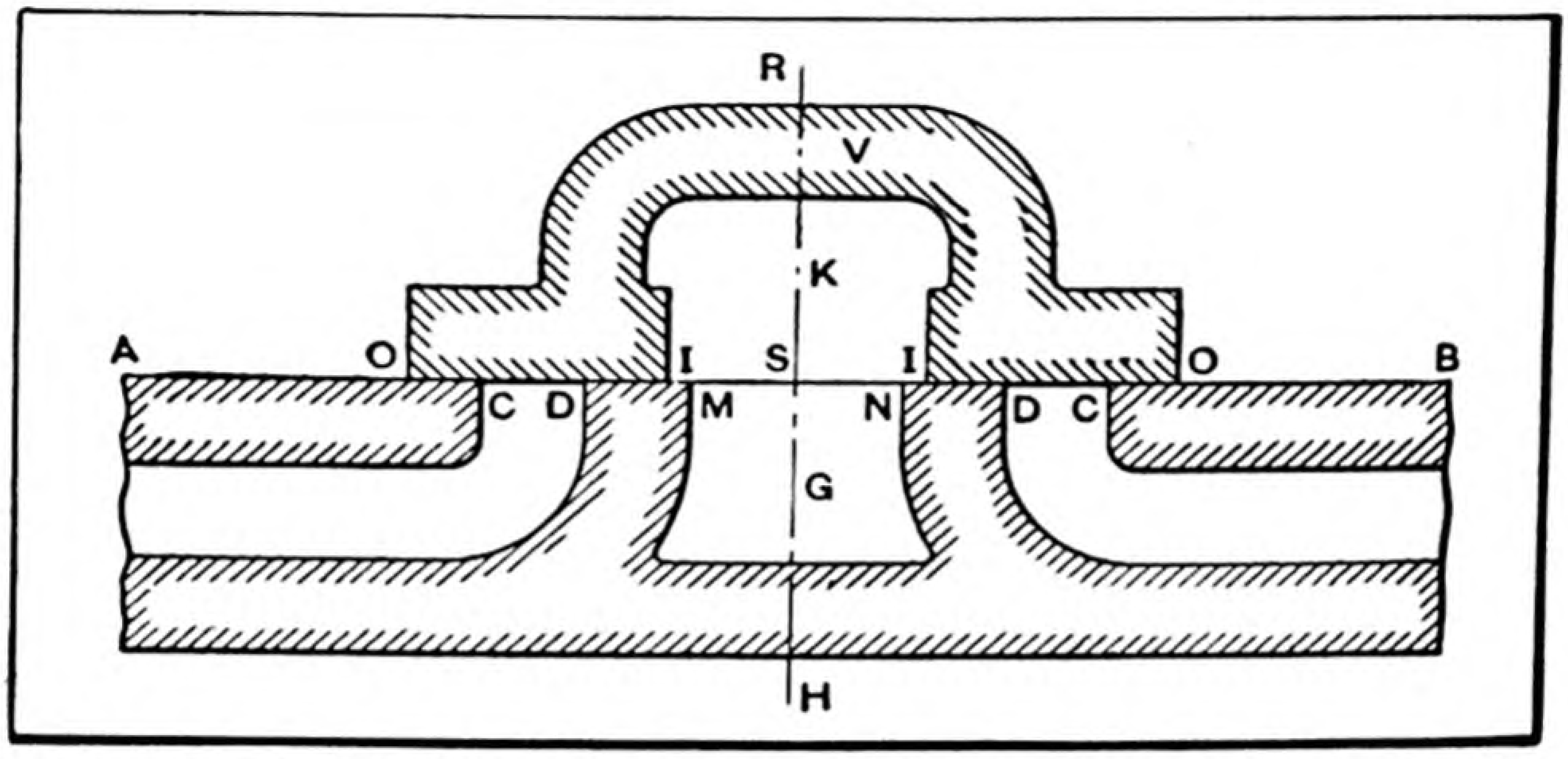


Fig. 1. Longitudinal Section of a Steam Engine Slide Valve and Ports

the piston has moved forward a certain distance, and be expanded during the remainder of the stroke. If there were no outside lap, steam would be admitted throughout the entire stroke and there would be no expansion. If there were no inside lap, exhaust would take place throughout the whole

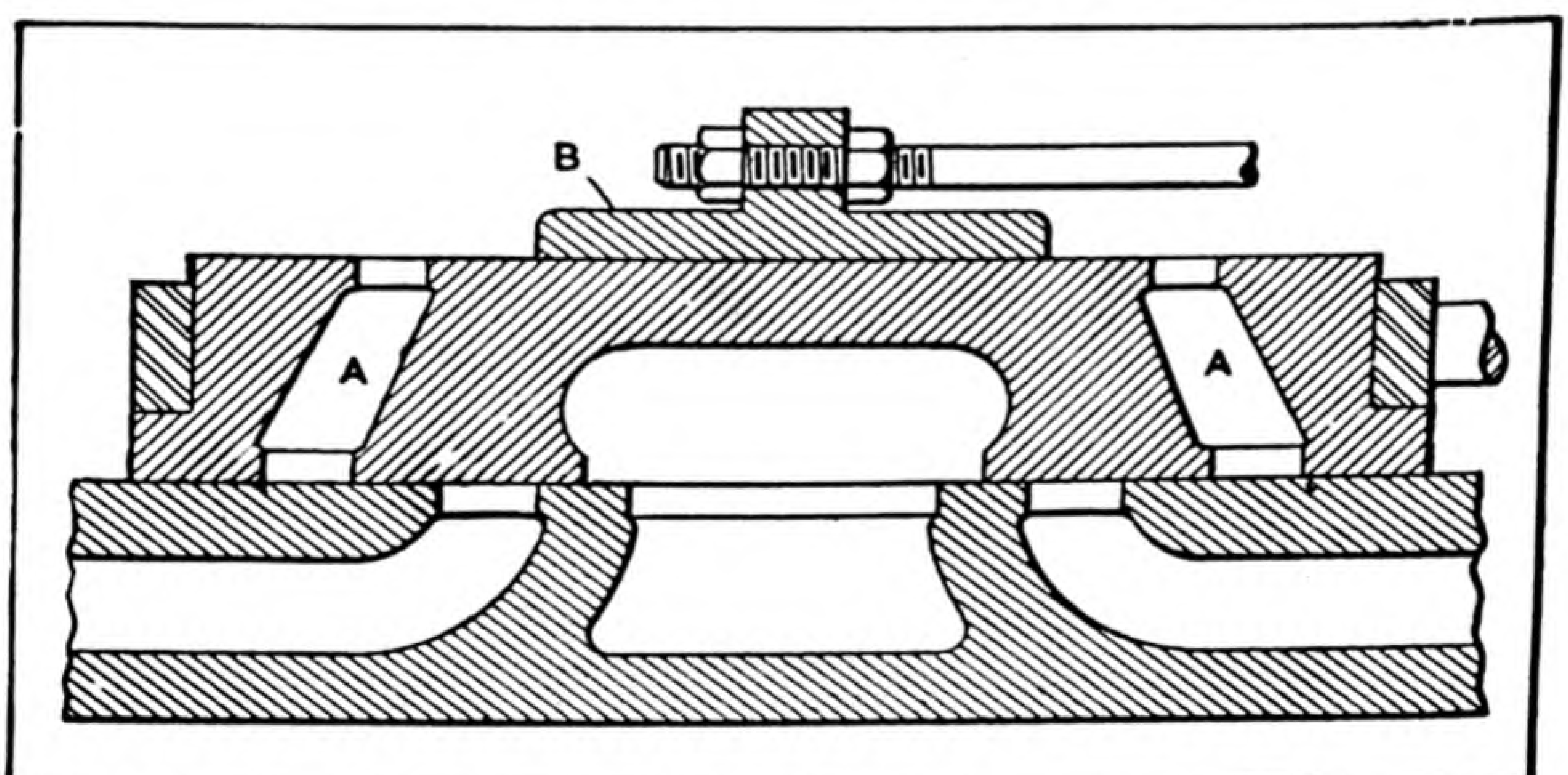


Fig. 2. Slide Valve having Auxiliary Cut-off Valve

stroke, and the advantages of premature release and compression would be lost. Hence, outside lap affects the cut-off, and inside lap affects release and compression.

Balanced Slide Valve. — Many of the slide valves now in use are of the balanced type, which means that the steam pressure is excluded from most of

the upper surface of the valve to reduce the pressure on the valve seat and the resistance to movement. There are different designs of balanced valves.

Riding Cut-off Valves. — If a steam engine is equipped with a single slide valve, any change in the point of cut-off will cause a corresponding change in the point of admission, thus varying the lead, release, and compression; hence, on many modern engines, the cut-off is varied independently by a separate auxiliary valve. The type of cut-off valve commonly used slides upon a bearing surface of the main or distribution valve, and, therefore, is often referred to as a "riding" valve. The main valve is operated by a fixed eccentric, and the riding valve by the eccentric of a shaft or flywheel type of governor, which varies the point of cut-off automatically, according to speed. For instance, if the engine speeds up, the position of the eccentric is changed with relation to the crank, so that the steam is cut off earlier, thus decreasing the speed, whereas, if the engine slows down as the result of an increase in load, the cut-off occurs later, which increases the power and brings the speed back to normal. This action of the governor, however, does not affect the operation of the main valve.

A simple form of riding cut-off valve is shown by the sectional view, Fig. 2. The main valve contains ports *A*, through which the steam is admitted to the cylinder, and the riding valve *B* serves to cut off the steam. The latter may be controlled by any of the different types of shaft governors in common use. Another valve mechanism which operates on the same principle, differs considerably in form, as both the main and cut-off valves are cylindrical, the cut-off valve working within the main valve. The inner or cut-off valve is operated by the eccentric controlled by the governor, and the main valve by the separate eccentric attached to the main shaft.

When setting riding or auxiliary cut-off valves, the general practice is to set the main valve the same as an ordinary slide valve, or so that it has equal port openings or lead at each end of the stroke, assuming that there is lead. The riding valve is usually set to give an equal cut-off for the forward and return strokes. When the riding valve is controlled by a shaft governor, which is the method commonly employed, the cut-off is equalized either at the middle of the range of the governor or at the point where it is expected that the engine will run most of the time. The exact method of procedure in setting the valves on engines of different design depends somewhat upon the arrangement of the valve-gear and governing mechanism, in each particular case.

SLIDE-VALVE LEAD. See Lead of Slide-valve.

SLIDE-VALVE, MEYER. See Meyer Valve.

SLIDING GEAR. A sliding gear is a gear mounted on a shaft parallel with another gear and capable of being slid out of or into engagement with

the other gear by moving it along its shaft. Gears of this type are employed in gear boxes for changing the rate of speed or feed of machine tools and are also employed in various other speed-changing devices.

SLIM TAPER FILE. Slim handsaw taper or slim taper files are like the ordinary handsaw files, but considerably lighter. They have largely superseded the regular handsaw files, the principal advantage being the greater sweep or stroke obtainable from the same section. There is also the *extra-slim taper* which is of lighter stock than the slim taper. Handsaw files are sometimes made in a blunt shape.

SLINGS. Slings are used in connection with hoisting apparatus for lifting loads and they are made either of chains, wire rope, or manila rope. Of these, chain slings are probably the most commonly used, but wire rope is employed at the present time more than formerly, and there are certain conditions under which manila rope is preferable.

SLIP. In blast-furnace operation, slip is the sudden settling of the material fed into the furnace through a considerable distance. It is caused by the bridging over of the material at some point well down in the furnace which bridging partly obstructs the gases, increasing the gas pressure in the lower part of the furnace. Slip may be accompanied by a violent puff of gas at the top.

SLITTING CUTTERS. Metal slitting cutters or slitting saws are used for cutting off stock or for milling narrow slots, like the screw-driver slots in screw-heads, and for similar purposes.

SLITTING FILES. A slitting file is a type that is similar to the feather-edge although the taper is less abrupt and the edges are sharper.

SLOTTING ATTACHMENT. A slotting attachment is sometimes used for adapting a milling machine to slotting. The tool-slide, which has a reciprocating movement like the ram of a slotter, is driven from the main spindle of the machine by an adjustable crank which enables the stroke to be varied. These varying strokes are indicated by a graduated scale on the front of the attachment. When the attachment is in use, a slotting tool of the required shape is clamped to the end of the slide. The slide swivels about the machine spindle and can be set at any angle from the vertical to the horizontal without affecting the length of the stroke. The setting is indicated by graduations on the side of the swivel-head. These angular adjustments are especially desirable when slotting out dies, in order to obtain the necessary clearance. Attachments of this type are largely used in connection with diemaking and tool-making, for slotting out small blanking dies, box tools for screw machines, etc.

SLOTTING MACHINES. The slotting machine or "slotter," as it is commonly called, operates on the same general principle as a shaper, except that the ram which carries the planing tool moves in a vertical direction and at right angles to the work-table. Slotters are used for finishing slots or other enclosed parts which could not be planed by the tool of a horizontal machine like a planer or shaper. The slotter is also used for various other classes of work requiring flat or curved surfaces which can be machined to better advantage by a tool which moves vertically. The slotting machine was originally designed for cutting keyways in pulleys, but practice soon demonstrated the adaptability of this machine for other branches of work. Therefore, while the primary purpose of the machine has been changed, the original name is still retained. The additional name applied to slotting machines usually indicates the design of the driving mechanism, or the nature of the work for which the slotter is used in case of special machines; thus there are *crank slotting machines* which have a crank drive, *geared slotting machines* which are equipped with gearing instead of a crank-driving mechanism, whereas *die slotters* and *locomotive frame slotters* are examples of the special machines designed for certain classes of work. See also Die Slotters.

SLUSH-CASTINGS. The process known as slush-casting is employed extensively in the production of ornamental objects made of spelter or zinc. In this process the metal in the mold is poured back into the ladle as soon as a thin layer next to the mold has set; thus, hollow and, therefore, relatively light castings are produced. The molds used are of metal, usually bronze or brass, which can be machined evenly and which will not be injured by the molten metal. The process is substantially as follows: The metal is poured into the hollow mold until it is full, and then the mold is immediately emptied, leaving a thin-walled casting chilled upon the inside surface. The mold is usually mounted upon trunnions or otherwise arranged to facilitate rapid emptying. Because of the extensive use for ornamental purposes, castings so produced are often plated, stained, or treated in other ways to produce color effects.

SLUSHING OILS. Slushing oils are materials used for protecting bright metal where it is not feasible to use paint, varnish, or other fixed coatings. An ideal slushing oil is one that can be easily applied to all kinds of metal surfaces by a variety of methods. It should coat the surfaces with a sufficiently thick and impervious film to exclude moisture and air (to prevent rusting), should remain in position for an indefinite length of time, and yet be completely removable from the surface without undue labor. The material should itself have no corrosive action on any kind of metal.

SMALL TOOLS. The expression "small tools" is generally used in the metal-working industries and is understood to mean such tools as taps, dies, reamers, milling cutters, drills, and counterbores; but the expression is not descriptive and it has been proposed that tools of this kind be called "metal-cutting tools," and the industry making them, the "metal-cutting tool industry." The latter name appears to be sufficiently descriptive. It has a definite meaning, not only within the machine-building industry, but also outside of that field.

SMELTER COKE. This is a coke fuel containing more than 1.2 per cent of sulphur and, therefore, not used for the smelting or melting of iron or steel, but often employed in the smelting of non-ferrous ores.

SMELTING. Smelting is the process of obtaining a metal from its ore by means of melting the ore and reducing the impurities, so that a nearly pure metal is obtained.

SMYRNA EMERY. Smyrna emery, also known as Turkish emery, is an abrasive obtained from the vicinity of Smyrna in Asia Minor. The value of the emery as an abrasive depends on the percentage of crystalline aluminum oxide that it contains. Smyrna emery contains about 57 per cent of this material, and, hence, is not as good as the best emery obtainable, that from Naxos, which contains 63 per cent.

SNAGGING CASTINGS. The removal of gates, sprues, fins, or other projections on castings, either by grinding or chipping and filing, is commonly known as "snagging." Grinding wheels are ordinarily used for this work, especially in foundries and wherever castings are produced in large quantities. The type of grinder that should be used for this work depends upon the size and shape of the castings. In general, castings weighing less than from 50 to 75 pounds are ordinarily ground on grinders of the floor-stand type or disk grinders, whereas heavier castings are ground either by swinging-frame or flexible-shaft grinders, because, when the castings are large and heavy, it is much more convenient to move the grinding wheel over the casting than to present the work to the wheel. When a floor-stand type of grinder is used, the castings are ordinarily supported on rests while being ground. In some cases, however, ordinary work-rests are not suitable, and it is preferable to support the castings by a chain or hoist suspended from an overhead trolley. Disk grinders are usually equipped with adjustable fixtures, and are used principally for grinding castings that are fairly uniform in size.

SNAP FLASKS. See Flasks for Molding.

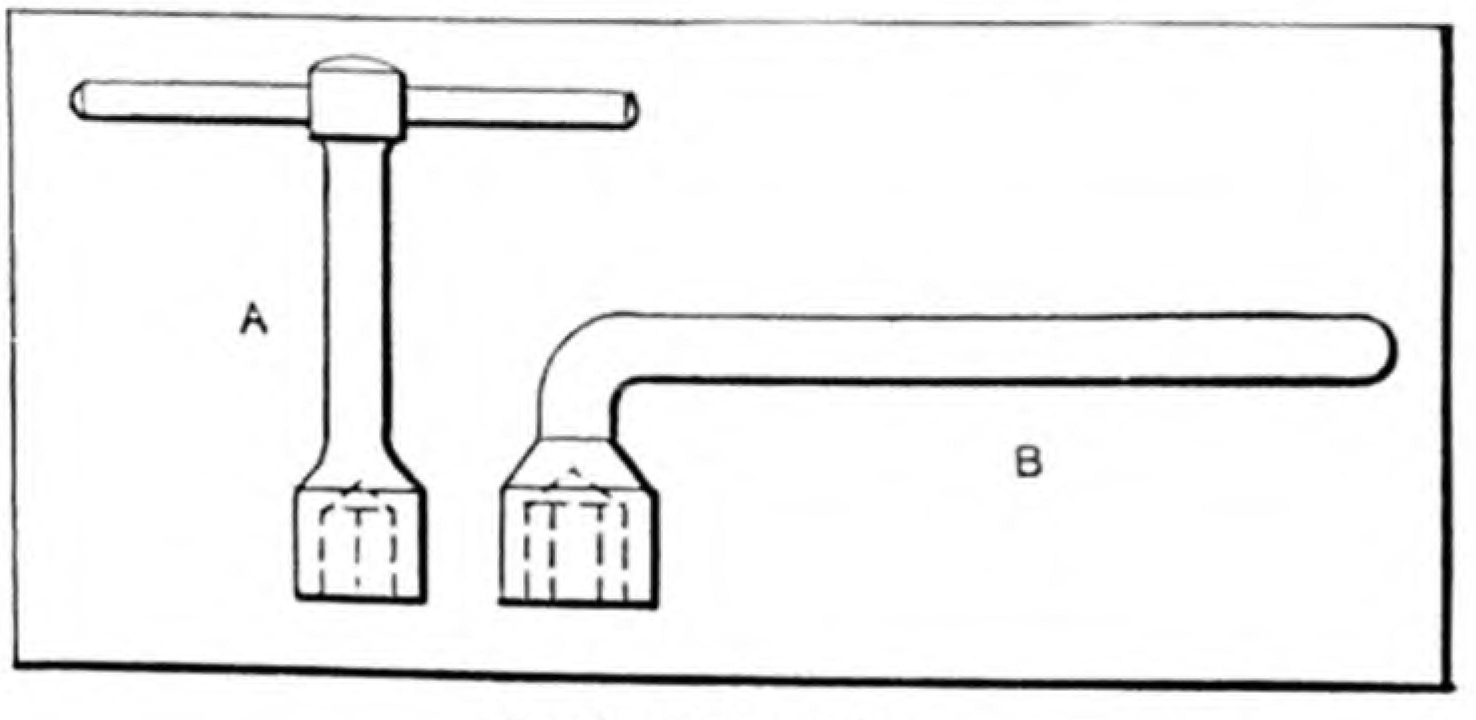
SNUB PULLEY. This is a pulley used in a belt conveyor installation to support the returning idle part of the belt.

SOAKING. When steel is kept in a furnace in order to insure thorough and uniform heating at a given temperature, this is commonly known as "soaking," the steel being allowed to "soak" at whatever temperature is required. In steel mills, a soaking pit is an underground furnace in which ingots are placed to obtain a uniform temperature preparatory to rolling.

SOAPSTONE. Same as Talc.

SOCKET-HEAD CAP-SCREWS. The socket-head type of cap-screw has either a hexagonal or square wrench socket formed in the end of a cylindrical head, so that the cap-screw can be turned (by inserting a wrench in the socket) until the head which enters a counterbored hole, is flush with the outer surface of the part held by the cap-screw. The socket-head cap-screw bears the same relation to ordinary cap-screws having projecting heads as the safety hollow set-screw does to ordinary set-screws.

SOCKET WRENCHES. Wrenches of this type are so named because the nut end is in the form of a socket. The *single-head straight socket wrench* *A* is made for confined situations, as in a hole, or in any other position where a wrench of the ordinary kind could not be used. In tightening jaws on a chuck, when the heads of the bolts are set flush, this type is generally used. It may be machined at the nut end for either hexagon or square-head bolts. The *offset socket wrench B* is useful in many cases for setting up bolts or nuts when the slipping of an ordinary wrench might break some part, or when the position of the bolt is such that it would be difficult to reach it with the ordinary type of wrench.



Socket Wrenches

SODA CLEANING SOLUTION. A soda solution which may be used for removing oil or grease from machine parts should contain about one-half pound of sal soda to each gallon of water. If old paint is to be removed, the solution should consist of about one-quarter pound of caustic soda to each gallon of water. As caustic soda is a strong alkali, care should be taken to prevent it from getting onto the hands. These solutions should be heated to the boiling point before immersing the parts to be cleaned; then the work will dry quickly after being removed, and will not rust. A wire basket or perforated bucket is

convenient for washing small pieces. The time required for cleaning depends somewhat upon the nature of the grease and to what extent it has dried and hardened.

Soda ash, the chemical formula of which is Na_2CO_3, has largely superseded potash solutions for cleaning purposes, because it is cheaper and, for most work, better than potash. The value of soda ash and potash solutions for cleaning purposes is that these chemicals combine with grease and, therefore, act as cleansing agents.

SODA PROCESS. This is a method for removing impurities, such as sulphates of lime and magnesia, from boiler feed water by means of adding carbonate of soda (soda ash) to the feed water.

SODIUM. Sodium is one of the metallic elements belonging to the alkali metal group, the chemical symbol of which is Na, and the atomic weight, 23.0. It is an element found abundantly in nature, but always in combination with other elements. Sodium possesses a silvery color, but, if exposed to the air, the surface is rapidly covered with a layer of hydroxide. The specific gravity is 0.98, making the weight per cubic inch 0.035 pound. Sodium melts at a temperature of 97 degrees C. (207 degrees F.), and boils at about 875 degrees C. (about 1600 degrees F.). The specific heat at 32 degrees F. is 0.293. At ordinary temperatures, sodium is as soft as wax and can be cut with a knife, but it hardens at very low temperatures. It ranks next to silver, copper, gold, and aluminum as a conductor of electricity, its electrical conductivity (silver = 100) being 32. It burns on heating in air with a yellow flame. With potassium, sodium forms a liquid alloy resembling mercury, which has been employed in high-temperature thermometers.

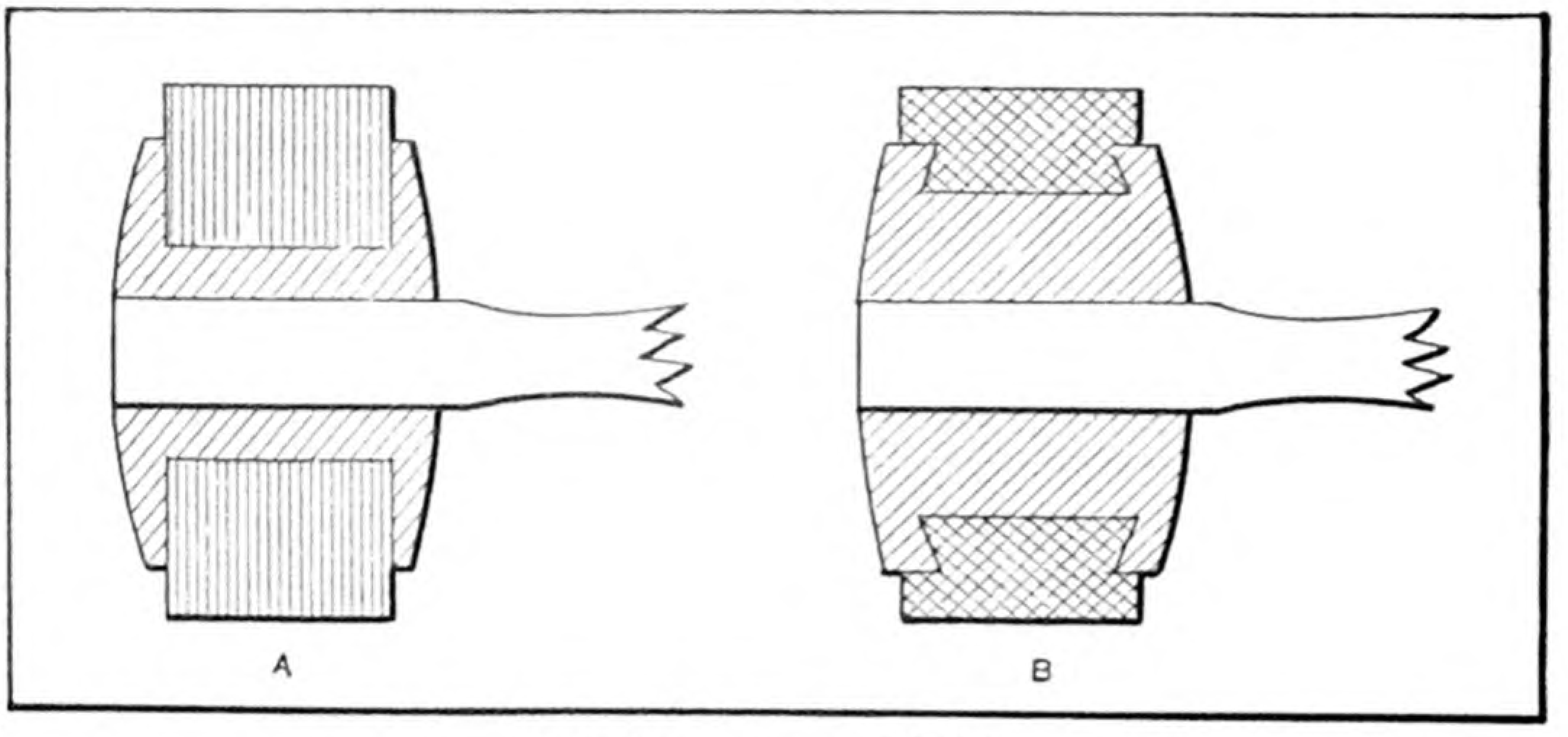
SOFT COAL. This coal contains from 50 to 75 per cent carbon and a large percentage of volatile matter, varying from 25 to 50 per cent. It is the same as Bituminous Coal.

SOFT COKE. Soft coke, also known as heating coke or jamb coke, is the coke obtained next to the back and front of the coke oven and around the oven doors when producing regular foundry and furnace coke.

SOFTENING PLANTS FOR WATER. See Water Softening Plants.

SOFT HAMMERS. "Soft hammers" are used in machine shops either to prevent marring finished surfaces or to avoid upsetting the ends of arbors, bolts, etc. Soft hammers are made of copper, babbitt metal, rawhide, or brass. A rawhide hammer is illustrated at *A* in the accompanying illustration. In this particular case the rawhide heads or faces are inserted in pockets formed in the body of the hammer, so that they

may readily be renewed. Diagram *B* illustrates a babbitt metal or lead hammer. In this case the lead or babbitt metal faces are held in the dove-tailed pockets shown. While a heavy blow may be struck with one of these



Soft Hammers or Mallets

soft hammers, a finished surface will not be marred by dents, because of the relative softness of the hammer face.

SOIL LOAD CAPACITY. See under Foundations for Machinery.

SOIL WEIGHT PER CUBIC FOOT. See Earth or Soil Weight.

SOLDER, BRAZING. See Brazing, Spelter Solder.

SOLDER, CADMIUM. See Cadmium Solder.

SOLDERING. Soldering is a process of joining metals together by means of an alloy which is melted into the joint, after the application of a suitable flux, and unites with the metals. The solder has a lower melting point than the metal to be joined. There are two general methods of soldering, namely, soft soldering and hard soldering. Ordinarily, soft solders are used when soldering with a heated copper bit or " iron " and the solder is an alloy of tin and lead, which melts at comparatively low temperatures. Hard solders are alloys of silver, copper, zinc, etc., and melt at very much higher temperatures than the soft solders. The hard soldering of copper, iron, etc., is generally known as *brazing*, and the solder, as *spelter*.

Solder. — Solder is almost always composed of an alloy of two or more metals. The solder used should have a lower melting point than the metals to be joined by it, but the fusing point of the solder should approach as nearly as possible to that of the metals to be joined so that a more tenacious junction is effected. *Soft solder* consists chiefly of lead and tin, although other metals are occasionally added to lower the melting point. The fusi-

bility of lead-tin alloys increases with the percentage of tin up to a certain point, but when the tin exceeds 67 per cent, the melting point rises gradually to the melting point of tin. Soft solders are termed common, medium, and fine, according to the tin content, those containing the most lead being the cheapest and having the highest melting points. Fine or "best" solder is largely used for soldering Britannia metal, brass, and tin-plate articles. The soft solder called "common" is used by plumbers for ordinary work, this solder containing two parts of lead to one part of tin. Fine solder is also used for soldering cast iron, steel, copper, and many alloys. Solder composed of two parts of lead and one part of tin is termed, in England, "plumbers' sealed solder." *Hard solders* for brazing are composed of copper and zinc, the composition varying according to the metal to be brazed.

Strongest Soft Solder. — Tests of tensile strength, based upon cast bars, sticks, and wires, indicate that the higher the tin, up to 73 per cent tin and 27 per cent lead, the greater the breaking strength. In the case of two pieces of tinned steel soldered together, the maximum strength is obtained with a solder containing about 60 per cent tin. Experience has shown that the strongest mixture for general soldering purposes is a solder composed of 57 per cent tin and 43 per cent lead, particularly if $\frac{1}{4}$ to $\frac{1}{2}$ per cent of antimony is added to the mixture. For mechanical soldering, 45 per cent should be the highest tin content, and for most dipping bath work, it has been demonstrated that tin from 35 to 40 per cent, according to the nature of the work, will give ample satisfaction, provided the solder is properly made.

Solder Wire. — The term "solder wire" is applied to wire which is extensively used in the manufacture of jewelry and which consists of a metal suitable for forming such objects as chain links, etc., and of a solder embedded in the wire either as a solid core or otherwise, to serve as the binding element. Metals commonly used in the manufacture of solder wire are pinchbeck, German silver, tin and so-called platinin and goldin metal, as well as gold and silver. Pinchbeck is the name applied to certain alloys which are closely related to brass alloys but contain less zinc. Common classes of pinchbeck alloys include similor, manheim gold, oveide and chrysorin.

Solder for Aluminum. —According to investigation by the Bureau of Standards, solder for aluminum should consist of a tin base with an addition of zinc, or zinc and aluminum. The function of the alloys is principally to produce a fluid mixture within the range of soldering temperatures. A high temperature is advised to secure adhesion of the tinned surface. For tin-zinc solders, the following composition is suggested: Zinc, 15 to 50 per cent, and the remainder tin. For tin-zinc-aluminum solders, the composition suggested is: Zinc, 8 to 15 per cent; aluminum, 5 to 12 per cent; and the remainder tin. By using the higher values of the zinc and aluminum percentages, the solder will be too stiff at the lower temperatures to

flow readily. A higher temperature will secure a better joint. Solders should be applied without a flux after preliminary cleaning and tinning of the surfaces to be joined. Good aluminum solder should not be brittle. The tensile strength of the better grades of aluminum solder is about 7000 pounds per square inch. The strength of the joint, however, is dependent upon the workmanship. All metals used for aluminum soldering are electrolytically negative to aluminum. A soldered joint for this reason is attacked by electrolysis and destroyed when exposed to moisture; hence it is recommended that the soldered joint be protected by paint or varnish.

SOLDERING ALUMINUM. See Aluminum Soldering.

SOLDERING, ELECTRIC. See Electric Soldering.

SOLDERING FLUXES. In order to obtain a good joint by means of soldering, it is necessary that there be more than mere adhesion between the solder and the metal. There must be an alloy formed between the metal and the solder, and, in order that this alloy may be formed, the surface of the metal must be entirely free from foreign substances, such as oxides, oils, or various kinds of solid matter. This is accomplished by using a flux that melts at the fusing temperature of the solder and thus excludes the air. The flux used in any case depends somewhat upon the nature of the work. The fluxes generally used for soft soldering are rosin, sal-ammoniac, and zinc chloride, although there are many others employed. For hard soldering or brazing, pulverized borax or boracic acid in powdered form are commonly used. Another flux that has given good results is made of equal parts, by weight, of borax and potash, this mixture being melted and, when cool, pulverized.

Soldering Paste. — The requirements of electrical work are such that in some cases an acid soldering flux cannot be used, and it is common practice to use what is known as a *soldering paste.* For soldering copper wires and other electrical conductors, a paste is unequalled and is especially adapted for work in which spattering and corrosion are objectionable.

SOLDER, SILVER. See Silver Solder.

SOLD-HOUR PLAN OF DISTRIBUTING OVERHEAD. The sold-hour plan of distributing expenses provides that the total direct labor wages in a department be divided by the number of hours worked in the same period to get a flat average cost per hour for labor. The time in hours consumed on any job is valued at this flat rate per hour, and the result is called the direct labor cost. The expense is applied on the man-hour method. This sold-hour method is not in very general use.

SOLENOID. As a magnet is a bar or mass of steel to which the peculiar properties of the loadstone have been applied, one generally understands

that an electric magnet is such a mass of electrified material that is given these peculiar properties by the application of the electric current. A magnet then, in simple terms, is a solid attracting body of material, while a solenoid is a hollow coil that has the power of attracting a body of magnetic material into itself or an electric magnetic helix. There are many and varied uses of solenoids in the operation of machinery with both alternating and direct current. The pull of an electromagnet varies as the square of the voltage, so that the effective pull at low voltage falls to less than one-half of what it is at the maximum.

SOLENOID BRAKE. One type of solenoid brake adapted for mill, crane and hoist motors and similar classes of service, is so arranged that the brake mechanism is held in the off or release position by a coil and plunger. The action is as follows: When power is applied to the motor the coil is energized and, consequently, the brake is released; when the power is shut off a spring-setting device forces the mechanism into the closed or braking position. Either a direct-current series solenoid or an alternating-current shunt solenoid can be mounted on the brake mechanism, these solenoids being interchangeable to permit operation either with alternating or direct current.

SOLID. In physics, the term solid is used to designate a substance in which the attractive force between the molecules is so strong that the form of the substance cannot be easily changed. Popularly defined, a solid substance is, therefore, one that has a definite form and a definite volume.

In mathematics, a solid is a body having three dimensions such as height, width, and length; the term "solid" is used in distinction to *surface*, which is a mathematical quantity which has width and length, but no height or thickness.

SOLUBLE OILS FOR CUTTING TOOLS. The soda water mixtures which formerly were used so extensively on metal-cutting tools to avoid some of the objections to the use of plain water, were at first mixtures of sal-soda and soft soap, combined with water in various proportions, the soft soap being added to give the required body to the mixture rather than for its lubricating qualities. As machine speeds increased, it was discovered that lubrication was required as well as cooling service, so it has become quite general practice to add some lard oil to the soda water. The addition of lard oil improved the lubricating capacity of the soda water cutting lubricants, but there are objections to its use on account of the free fatty acid developed, particularly in the presence of heat; the deterioration if used repeatedly as a cutting lubricant; the high cost; and the loss in the cooling capacity after repeated use. Soda water has little more lubricating value than has plain water; hence, the lubricating qualities of various other

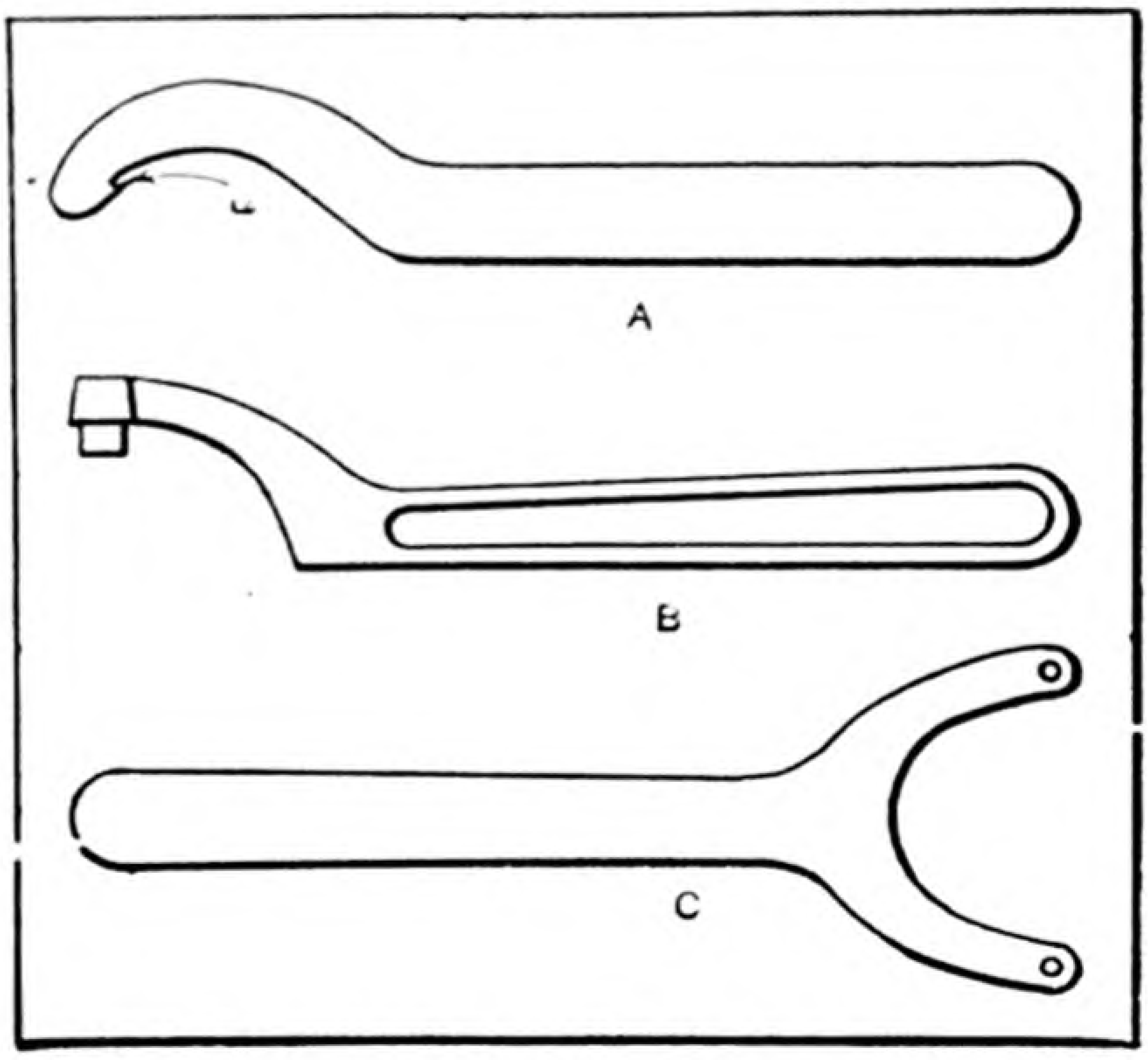
oils would be as efficacious if the oils were simply emulsified with water. In fact, better results are obtained by compounding various oils which blend (that is, form stable emulsions) immediately with cold water. These soluble cutting oils are used extensively for machining operations requiring flooded lubrication of cutting tools.

SORBITE. Sorbite is a constituent obtained in steel when drawing the temper of hardened steel to a temperature somewhere between 400 and 800 degrees C. (750 and 1470 degrees F.). It reaches its maximum at 600 degrees C. (1110 degrees F.). See also Steels.

SPACING TABLES. In order to avoid laying out rivet holes in plates prior to punching, spacing mechanisms are often used in conjunction with punching machines. The plate or other part to be punched is carried by a table that is shifted an amount equal to the spacing required between the holes. This spacing table may have either a hand or automatic feed. The mechanism of an automatic spacing table is so designed that the table is shifted as soon as the punch has moved up far enough to clear the work, the movement being completed before the punch again engages the stock. For girder work, where the rivet spacing may vary in each row, the problem of spacing is more difficult than in the case of boiler work, where the spacing is uniform on each seam. Mechanical spacing devices for girder work may be partly automatic so that the machine continues a given spacing until it is changed by the operator or the machine may follow a templet previously set for the required spacing and be entirely automatic.

SPAN. This is an old length measure, equal to 9 inches.

SPANDREL. A spandrel (or fillet) is a plane figure or surface enclosed between a circular arc, equal to one-fourth of the complete circle, and two tangents to the circle at the extreme ends of the arc. If the radius of the circular arc equals r, then the area of the spandrel equals $0.215\ r^2$.



Spanner Wrenches

SPANNER WRENCHES. Cylindrical nuts are occasionally provided with shoulders or milled slots for purposes of adjustment, and, in cases of this kind, a hook-type spanner wrench, such as that shown at *A*, is needed. The portion *a* is so made that it will enter any one of the slots and

serve as a means for tightening the nuts. The single pin-type of wrench, *B*, is used for the same kind of work as style *A*; radially drilled holes around the periphery of the nut are provided, so that the pin will enter any one of these holes. There are many cases when a cylindrical nut is set into some portion of a machine in such a way that there is no protruding portion to which a wrench of the ordinary type can be applied. In cases of this kind, several holes may be drilled in the face of the nut so that the pins in the wrench shown at *C* can be used to give the necessary grip, when adjustment is needed.

SPARK PLUG STANDARDS. The S. A. E. standard spark plugs have screw threads of the U. S. standard or American form, 18 threads per inch, and the outside diameter of the screw thread is $\frac{7}{8}$ inch. The hexagon heads are in two sizes, the small hexagon having a width across the flats of $\frac{15}{16}$ inch and the large hexagon, $1\frac{1}{8}$ inches. The firing points should not project below the shell more than $\frac{3}{16}$ inch and the minimum distance from the spark plug seat to the nearest object over the spark plug should be $2\frac{3}{4}$ inches.

SPARK TESTS FOR STEEL. It has long been the practice of toolmakers and hardeners to judge the grade of steel by observing the characteristics of the spark produced when a sample is held against an abrasive wheel. It is doubtful if anyone could estimate within plus or minus 0.10 per cent of carbon, unless the grinding wheel speed and the type and grade of wheel have been standardized, and unless analyzed steel standards from the same heat as the steel being tested are available. But if wheel speed and wheel are standardized and a standard from the same heat is available, then it is possible to estimate the carbon content to within plus or minus 0.02 per cent for the lower carbon steels, and to within plus or minus 0.05 per cent for the higher carbon steels.

The carbon content of alloy steel may be determined as accurately as for the straight carbon steels, provided the percentage of alloying elements is not very high, as would be the case, for instance, in high-speed steel. In addition, the presence of other elements may be determined. The presence of chromium can readily be determined within ranges of 0.3 per cent; nickel below 1.5 per cent is somewhat difficult to determine, but nickel from 1.5 to 3.5 per cent is readily discerned. In tungsten steel, one may discover minute traces of tungsten, and also distinguish between 2 per cent, 5 per cent, and 8 per cent tungsten steel and higher. The beginner should become accustomed to the carbon steels first, for after he has become thoroughly conversant with these, the examination of other steels will be easier.

Spark Pictures. — In looking at the spark picture produced by carbon steel, when pressed against an abrasive wheel, a series of streaks and explosions are in evidence. By observing at first, steels of known composi-

tion, and perhaps keeping samples as standards for comparison, other steels may be classified in a general way by the spark test. The piece of steel to be tested should not be placed against the edge of the wheel. It has been found more satisfactory to place it against the side surface of the wheel at a point $\frac{1}{4}$ to $\frac{1}{2}$ inch from the outer periphery. There should be no obstruction in front of the spark, as it is generally easier to study the characteristics at a distance from the wheel at a point where the carrier lines are more separated. A black background should be used, against which the sparks can be clearly seen. The best way is to set the wheel in a black painted cabinet, so that the color and characteristics can be readily seen. The length of the spark has little to do with the determination of the grade of steel, because the length usually depends on the size of the piece being tested and the method of pressing it against the wheel. The only difference in the method of testing hardened and annealed work is that more pressure is required to obtain the same length of spark with an annealed piece of work.

SPECIFIC GRAVITY. In the case of solid bodies, specific gravity is a number indicating how many times a certain volume of a material is heavier than an equal volume of water. As the density of water differs slightly at different temperatures, it is the usual custom to make comparisons on the basis of water at a temperature of 62 degrees F. The weight of one cubic inch of pure water at 62 degrees F. is 0.0361 pound. If the specific gravity of any material is known, the weight of a cubic inch of the material can, therefore, be found by multiplying its specific gravity by 0.0361. To find the weight per cubic foot of a material, the specific gravity of which is known, multiply the specific gravity by 62.355. If the weight of a cubic inch of a material is known, the specific gravity is found by dividing the weight per cubic inch by 0.0361. If the weight per cubic foot of a material is known, the specific gravity is found by multiplying this weight by 0.01604. The *specific gravity of liquids* is the number which indicates how much a certain volume of the liquid weighs compared with an equal volume of water, the same as in the case of solid bodies. The specific gravity for liquids heavier than water equals 145 ÷ (145 − degrees Baumé). For liquids lighter than water, the specific gravity equals 140 ÷ (130 + degrees Baumé). The *specific gravity of gases* is the number which indicates their weight in comparison with that of an equal volume of air. The specific gravity of air is 1, and the comparison is made at 32 degrees F.

SPECIFIC GRAVITY MEASUREMENT. See Hydrometer.

SPECIFIC HEAT. The specific heat of a given substance is the ratio of the heat required to raise the temperature of a certain weight of the substance one degree F. to that required to raise the temperature of the same weight of water one degree. As the specific heat is not constant at all tem-

peratures, it is generally assumed that it is determined by raising the temperature from 62 to 63 degrees F. For most substances, however, it is practically constant for temperatures up to 212 degrees F. Considerable difficulty has been experienced in determining the specific heat accurately. In the case of solid bodies and liquids, methods have been developed by means of which the specific heat has been determined to within an accuracy of probably 0.5 per cent, but in the case of gases, the specific heats are less accurate, as evidenced by the fact that different investigators give somewhat different values. The fact that slight impurities in solids, liquids, and gases affect the specific heat must also be taken into consideration. Hence, the figures given in any table of specific heat may be expected to vary slightly from figures given in other tabulations.

Specific Heat of Air. — The specific heat of air, or the heat units required to raise the temperature of one pound of air one degree Fahrenheit, equals, at constant pressure, 0.2375 B.T.U. (British Thermal Units), and at constant volume, 0.1689 B.T.U.

SPECULUM. Speculum metal is the technical name which is applied to the alloy of which telescope mirrors or reflectors are made. Its composition is two parts copper and one part tin. The addition of 1 or 2 per cent metallic arsenic gives the metal a greater compactness and a greater luster and hardness, but if such addition is made, the metal is likely to tarnish. The metal is very hard and as brittle as sealing wax.

SPEED-CHANGING MECHANISMS. When speed variations are essential to the operation of machines such, for example, as are used for some kinds of manufacturing work, the changes are usually obtained by hand-controlled speed-changing devices. If such variations are seldom required, it may be necessary to stop the machine and make an adjustment, or replace one or more gears with others of different diameters. When changes of speed are frequently needed, the machine is generally equipped with some mechanical device enabling one or more variations to be obtained rapidly, by simply moving a wheel, lever, or rod which controls the combination or velocity ratio of the mechanism through which the motion is transmitted. If the machine is of the automatic type, the speed may be regulated according to varying conditions, by the mechanism of the machine itself, which is constructed or adjusted beforehand to give the proper changes. The exact arrangement of the details depends, in any case, upon conditions such as the speed variation required, the importance of rapid changes, the relation of the speed-controlling mechanism to other parts of the machine, etc.

Mechanical devices for varying the speed are of special importance on machine tools. In fact, most machine tools are so constructed that the

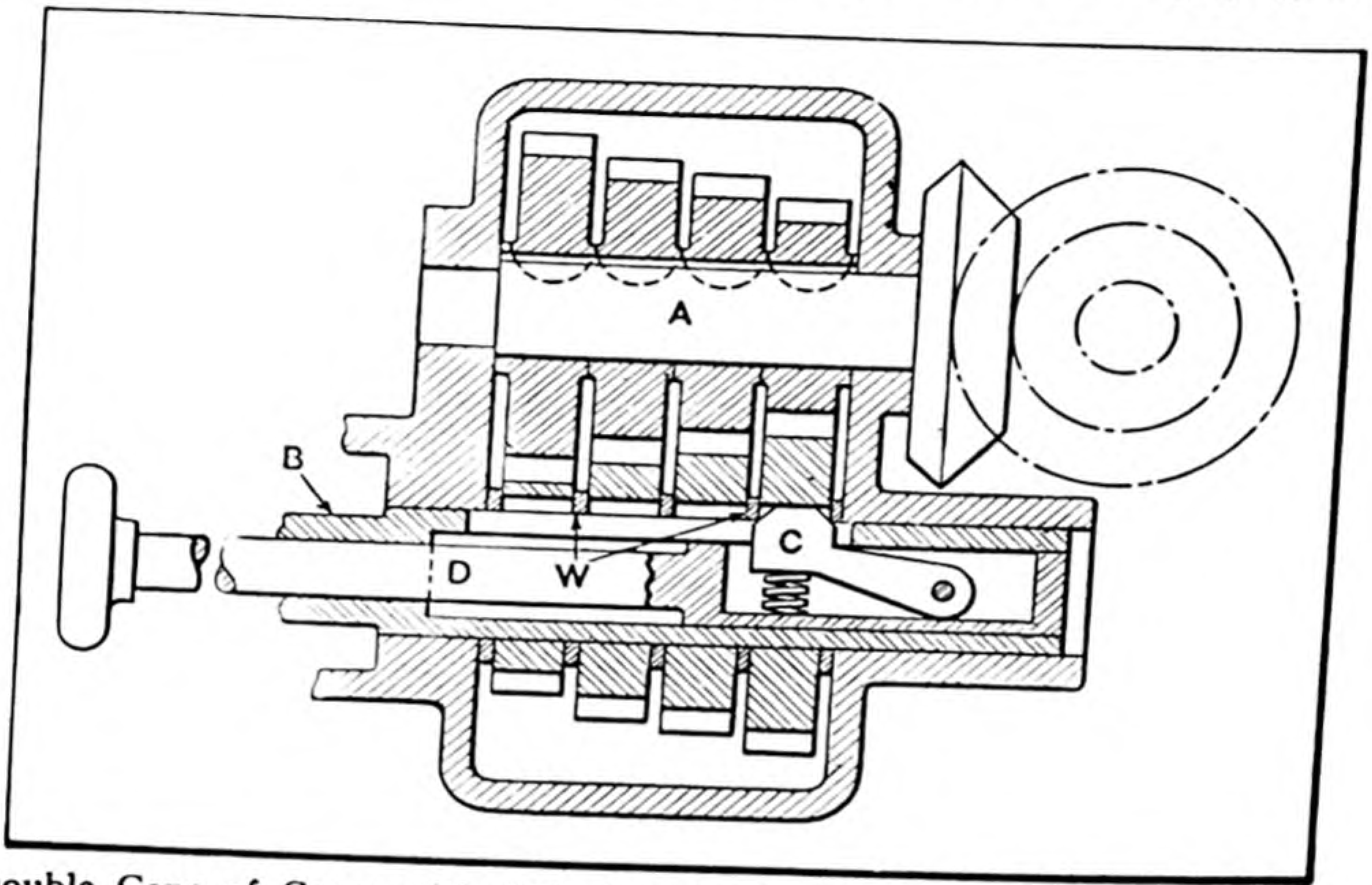
speed of the cutting tool or of the part being operated upon can be varied, the range or extent of the variation depending upon the type of machine. These changes are desirable in order to cut different kinds of metal at the most efficient speed. Another important reason for speed variation is to secure the proper surface speed for revolving parts, regardless of the diameter, and the correct cutting speeds for rotating tools of different sizes.

Types of Speed-changing Mechanisms. — When a variation of speed is obtained by changing the velocity ratio of two or more parts forming a train of mechanism, one of the following methods is generally employed: (1) By means of conical pulleys connected by a belt or cone-pulleys having "steps" of different diameters upon which a connecting belt may be shifted; (2) by the use of cone-pulleys in conjunction with one or more sets of gears; (3) by means of toothed gears exclusively, with an arrangement that enables the motion to be transmitted through different ratios or combinations of gearing; (4) by employing a friction transmission consisting of driving and driven disks, pulleys, or wheels, so arranged that one member (or an intermediate connecting device) can be shifted relative to the axis of the other for varying the speed. These different types or classes of speed-changing mechanisms are constructed in various ways.

When toothed gearing is used exclusively in a speed-changing mechanism, the most common arrangements may be defined as the sliding-gear type; the clutch-controlled type; the gear-cone and sliding-key type; the gear-cone and expanding-clutch type; the gear-cone and tumbler-gear type; and the multiple crown-gear and shifting-pinion type.

Double Gear Cone Transmission. — Speed changes for many types of machine tools and other classes of machinery, are obtained by some form of geared transmission. The speed ratio between the driving and driven shaft usually is obtained either (1) by shifting gears to bring different combinations into mesh; (2) by shifting clutches which cause the motion to be transmitted through different combinations; (3) by using a double gear cone and a shifting key as shown by the illustration. This latter method is often employed (in connection with the feeding mechanisms of machine tools, etc.) One cone of gears (the number of which is varied according to requirements) is attached to the driving shaft *A*, whereas the gears of the other mating cone are free to rotate upon the shaft *B*, except when locked to it by a "diving key" or plunger *C* which can be moved from one gear to another by means of a rod *D* that is shifted in some suitable way. This rod may simply have a knob on the end, as indicated in the illustration, so that it can be pulled out or pushed in, or it may be attached to a hand-lever to facilitate moving it. When the diving key is in the position shown in the illustration, the mechanism will give the slowest speed, since the largest gear of the driven cone is clutched to the shaft *B*. Obviously, each

individual gear of the lower cone may be successively locked to the driven shaft by pulling rod D and key C forward. As the illustration indicates, the key is pivoted at one end, and, as it is shifted from one gear to another, the beveled edges engage the wards W, which cause the key to move radially inward out of engagement with one gear before engaging the next.



Double Cone of Gears with "Diving Key" which Controls Speed Changes

These wards are simply washers placed between the different gears, and they cause the key to be entirely disengaged from one gear before engaging the next successive one in the cone; moreover, the operation of changing from one speed to another is facilitated by these wards, inasmuch as the pressure required to disengage the key radially is somewhat less than would be necessary if the key were simply moved longitudinally.

Speed Variations and Gear Ratios. — Proportioning a train of gears to obtain a given velocity ratio, or possibly a given series of speeds, is frequently encountered in the design of geared transmissions. When the problem is simply that of obtaining a given velocity ratio, and when the latter is so large that more than one pair of gears should be used, a uniform reduction between the different pairs is conducive to the highest efficiency. Whenever this arrangement is practicable, the ratio of each pair in a train may be determined by extracting the root of the total ratio. If there are two pairs of gears, extract the square root; for three pairs, extract the cube root, etc. For example, if the total ratio between the first driving and the last driven gear is to be 125 to 1 and three pairs of gears are to be used, the ratio of each pair should preferably equal 5 to 1, since $\sqrt[3]{125} = 5$.

In designing gear combinations for varying spindle speeds or feeding

movements, it is general practice, among machine tool builders particularly, to vary the speeds in geometrical progression, successive speeds being obtained by multiplying each preceding term by a ratio or constant multiplier. Thus, if the slowest speed is 50 revolutions per minute and the ratio is 1.3, the succeeding speeds will equal $50 \times 1.3 = 65$; $65 \times 1.3 = 84.5$; $84.5 \times 1.3 = 109.8$.

When the fastest speed F and the slowest speed S in a series are known and also the total number of speeds N, the ratio may be determined by the well-known formula:

$$\text{Ratio} = \sqrt[N-1]{\frac{F}{S}}$$

Since logarithms would ordinarily be used for the extraction of this root, the ratio may be obtained as follows:

Rule — Subtract the logarithm of the slowest speed from the logarithm of the fastest speed and divide the difference by the total number of speeds minus 1; the result will equal the logarithm of the ratio.

In actual practice, the exact progression obtained may be modified slightly to permit using gears of a certain diametrical pitch. For machine tool transmissions, the speed ratio should, as a general rule, be between 1.3 and 1.5, as otherwise there will be either too small or too great a difference between successive speeds. There would be no practical advantage in a series of speeds varying by small increments equivalent to a ratio of say, 1.1, whereas, if the ratio were 1.7 or possibly 2, the changes from one speed to the next would be excessive. Feeding mechanisms may be designed for ratios of 1.2 or less, depending on the type of machine.

Speeds of machine tool drives and especially feed changes are sometimes varied according to "chromatic scale progression," with a ratio of either 1.4142 or 1.189 in case a lower ratio is required. The first ratio is the square root of 2, and the second the fourth root of 2. The object of using these particular ratios is to obtain a series of speeds or feeds containing the even ratios, 2, 4, 8, 16, etc.

SPEED, CRITICAL. See Critical Speed.

SPEED INDICATORS. The simplest instruments for determining the speeds of shafts, etc., are commonly called *speed indicators* or *revolution counters*. A typical form of speed indicator has a spindle that is held into engagement with the center of a revolving shaft, thus transmitting rotary motion to a dial or pointer. Each revolution of this pointer or dial, which turns much slower than the shaft, is equivalent to a certain number of revolutions of the shaft. For instance, one turn of a pointer may represent 100 revolutions, and the number of revolutions for any fractional part of a turn

is indicated by suitable graduations. To obtain the speed in revolutions per minute, this instrument is used in conjunction with a watch. Another form of speed counter is so arranged that the revolutions made during a given time are indicated by figures which change automatically. For instance, if the reading is 500 at the instance the spindle of the instrument is pressed against the shaft and 700 one minute afterward, the difference between the first and second readings, or 200, indicates the speed in revolutions per minute. If considered desirable, the register may be set to zero by holding the point of the spindle against the revolving shaft for a short time. A more highly developed instrument known as a *tachoscope* consists of a revolution counter and a non-magnetic precision stop-watch which are so connected that they operate simultaneously the moment a slight pressure is applied to the spindle which engages the revolving shaft. As soon as the pressure is released, both the revolution counter and the watch stop at the same time, thus indicating on the dials the number of revolutions made and also the time elapsed. See also Tachometer.

SPEED LATHE. The name "speed lathe" is usually applied to light lathes which have neither back-gears nor a tool carriage, and are intended for rotating parts rapidly either for polishing, hand turning, or filing. When turning parts by hand-manipulated tools, the ends of the tools are supported by a T-shaped rest that is clamped to the bed. Lathes of this class are sometimes known as "hand lathes." Many lathes of the "speed" class have either a lever or a combination lever-and-screw feeding motion for the tailstock spindle, the lever being very convenient for feeding drills or reamers which are held in the end of the spindle. The term "speed lathe" is also applied by some manufacturers to a design which has a hand-operated carriage, and one that is without back-gears or a power feeding mechanism.

SPEED RANGE, CHROMATIC. See Chromatic Speed Range.

SPEED REDUCERS. A speed reducer for obtaining a reduction of speed between driving and driven shafts consists of a combination of gearing enclosed in a housing to form a self-contained unit. The housing serves to protect the gearing from dust, etc., and to retain lubrication. It also acts as a safeguard by enclosing the gears. Speed reducers may be classified according to the type of gearing. For example, some speed reducers have spur gears, others herringbone gears, and a third class, worm gearing. The reduction ratios cover a wide range and may vary from $1\frac{1}{2}$ or 2 to 1, up to 5000 to 1 or higher in single units. If these units, however, are combined so that the driven shaft of one unit connects with the driving shaft of another, ratios that are much higher than ever required in practical work may be obtained readily. See also Speed-changing Mechanisms.

SPELLERIZING. A process known as "spellerizing" has been developed to increase the life of pipe steel. By this process, the steel is treated mechanically and it consists in first subjecting the skelp, at a proper temperature, to the action of rolls having regularly-shaped projections on their working surface. The skelp is then subjected to the action of smooth-faced rolls, and by repeating these rolling operations, the surface of the metal is worked so as to produce a uniformly dense texture which is better adapted to resist corrosion, especially in the form of pitting.

SPELTER AND SPELTER SOLDER. Spelter is a name which, in the past, was frequently used for zinc, but which, at the present time, is used only commercially, and then only when it refers to zinc cast in ingots. Spelter solder, an alloy of copper and zinc, used in hard soldering or brazing, is also frequently spoken of simply as "spelter," but in that case the expression is an abbreviation of the term "spelter solder."

SPHERICAL CANDLE POWER. The spherical candle power, or "mean spherical candle power," of a lamp, is the average candle power of the lamp in all directions.

SPHEROID. A spheroid or an *ellipsoid of revolution* is formed by an ellipse rotating about one of its axes, thereby forming a solid of revolution. A spheroid may also be defined as an ellipsoid in which two axes are equal.

SPHEROIDIZING. According to the S. A. E. definition, spheroidizing is the prolonged heating of iron-base alloys at a temperature near, but generally slightly below, the critical temperature range, followed usually by relatively slow cooling. In the case of small objects of high-carbon steels, the spheroidizing result is obtained more rapidly by prolonged heating to temperatures alternately within and slightly below the critical temperature range. The object of this heat-treatment is to produce a globular condition of the carbide.

SPIEGELEISEN. Spiegeleisen, a German term adopted for an alloy of manganese and iron, contains about 12 per cent of manganese and 4 per cent of carbon, with the remainder iron. The term "spiegeleisen" means "mirror iron," this name being given to the alloy on account of the brilliancy of its fracture. Spiegeleisen is used in the Bessemer process of making steel, for recarburizing the molten charge in the Bessemer converter. The spiegeleisen is added in a molten state.

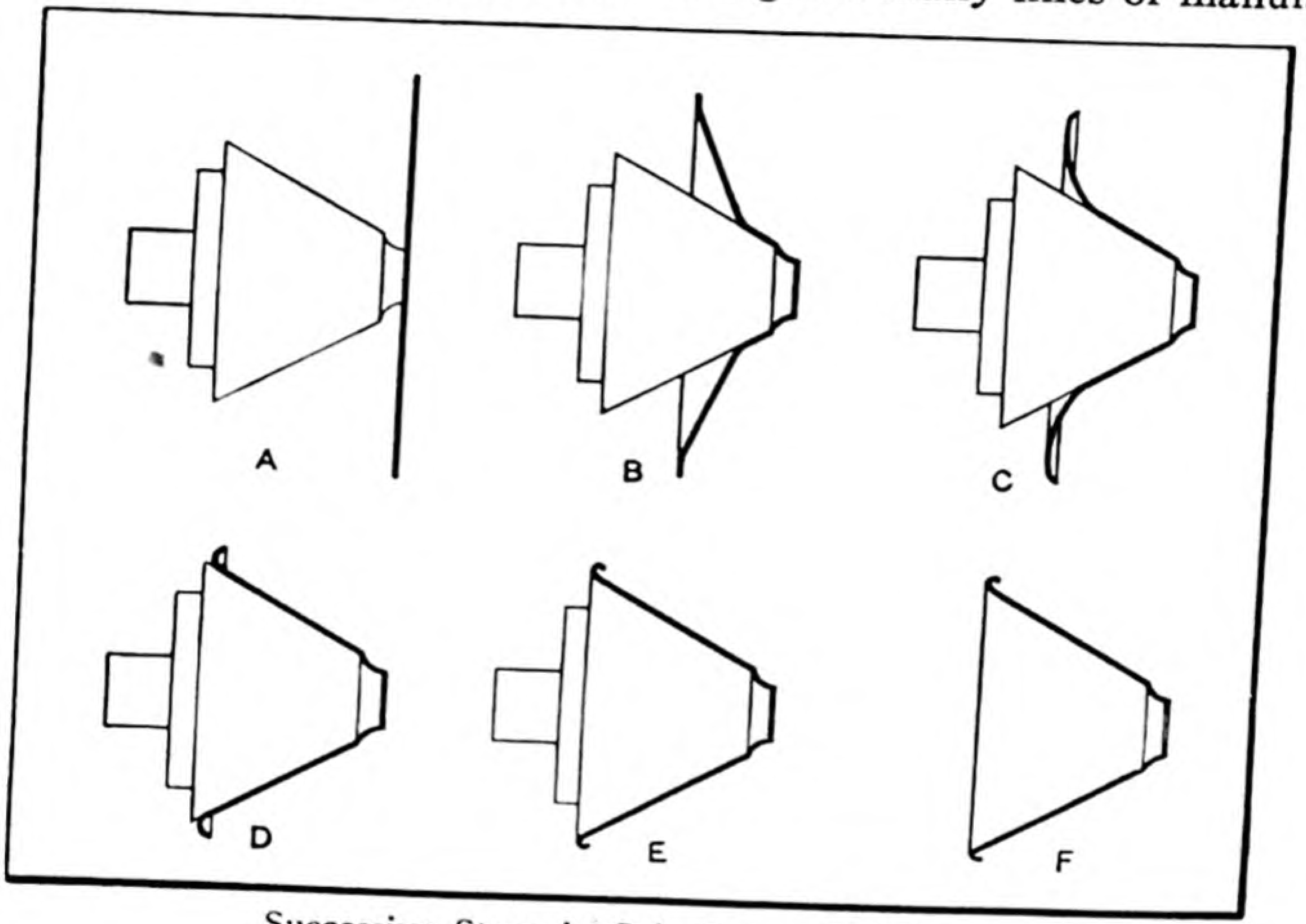
SPIKE-HOLDING QUALITIES OF WOODS. See Nail-holding Qualities of Woods.

SPINDLE. In general, a spindle is a cylindrical machine part, generally capable of being rotated and, usually, the main or most important shaft

in a machine. A lathe spindle, for example, is the shaft mounted in the headstock bearings, in the end of which the live center is held and from which the work in the lathe is driven.

SPINDLE, STANDARD MILLING MACHINE. See Milling Machine, Standard Spindle.

SPINNING METALS. The formation of sheet-metal parts into circular shapes by means of a lathe, forms and hand tools which serve to press and shape the metal about the revolving form, is known as *metal* spinning. The products of metal spinning are used in a great many lines of manufacture.



Successive Steps in Spinning a Reflector

Examples of this work are chandelier parts, cooking utensils, silver and britannia hollow-ware, automobile lamps, cane-heads, and many other sheet-metal specialties. Brass, copper, zinc, aluminum, iron, soft steel, and, in fact, nearly all metals yield readily to the spinner's skill. At best, spinning is hard physical work, and the softer the stock, the easier and quicker the spinner can transform it into the required product. Successive steps in spinning a copper head-light reflector are shown by the accompanying diagrams.

SPIRAL AND HELIX. A spiral may be defined mathematically as a curve having a constantly increasing radius of curvature. Spirals are often confused with helices, as for instance, when speaking of "spiral" gears or "spiral-riveted" pipe, which should properly be termed "helical" gears and "helical-riveted" pipe. Both the spiral and the helix are exemplified

in spring design, the spiral being represented by a watch spring, while the helix is represented by a coil spring.

SPIRAL BEVEL GEAR. Spiral type bevel gears have been used widely in automobile rear axle drives in preference to bevel gearing having straight teeth. There has also been an increasing demand for this type of gearing for other purposes. The spiral design operates more smoothly than bevel gears with straight teeth and has certain other advantages. The relation between spiral and straight tooth bevel gearing is practically the same as the relation between ordinary spur gears and helical gears applied to parallel shafts. The teeth of spiral bevel gears are not a true spiral, although the actual curve, when developed on a plane, closely approximates the spiral curve. Gears of this kind are cut on machines of the generating type.

SPIRAL BEVEL GEAR CAPACITY. Spiral bevel gears have a load-carrying capacity that is somewhat greater than that of straight-tooth bevel gears of similar proportions. The difference in capacity, however, is not very great, and the formula for straight-tooth gears may also be applied to the spiral bevel type. One of the principal reasons why spiral bevel gears are slightly superior to the straight-tooth form as power transmitters is that there are more teeth in contact and the load on any one tooth is less. Another reason is that the load is never concentrated on the point of a tooth throughout its whole length. When there is contact at the point at one end, the contact is toward the flank at the other end, and the average height from the root, at which the load is applied, is much less than the total height of the tooth. The smoothness of operation is another favorable factor tending toward greater load capacity, as in the case of herringbone or double-helical gearing for connecting parallel shafts.

The tooth of a spiral bevel gear has to take both the transmitted load and the thrust load. This total load equals the transmitted load divided by the cosine of the spiral angle. For a 30-degree spiral angle, the total load is about 1.15 times the transmitted load. This additional tooth load on a spiral bevel gear tooth, as compared with a straight tooth, is more than offset by the increased number of teeth in contact. While the tooth thickness of the spiral bevel gear is less than that of the straight gear, the length of the curved tooth is correspondingly greater, so that the sectional area on the pitch cone surface is practically the same for the straight and spiral forms of teeth of corresponding pitch.

SPIRAL GEARING. Gears which have a pitch surface cylindrical in shape, and in which the axes of the teeth are not straight lines, as in spur gearing, but form a helix on the surface of the pitch cylinder, are often called *spiral* gears. The terms " spiral " gear and " helical " gear are syn-

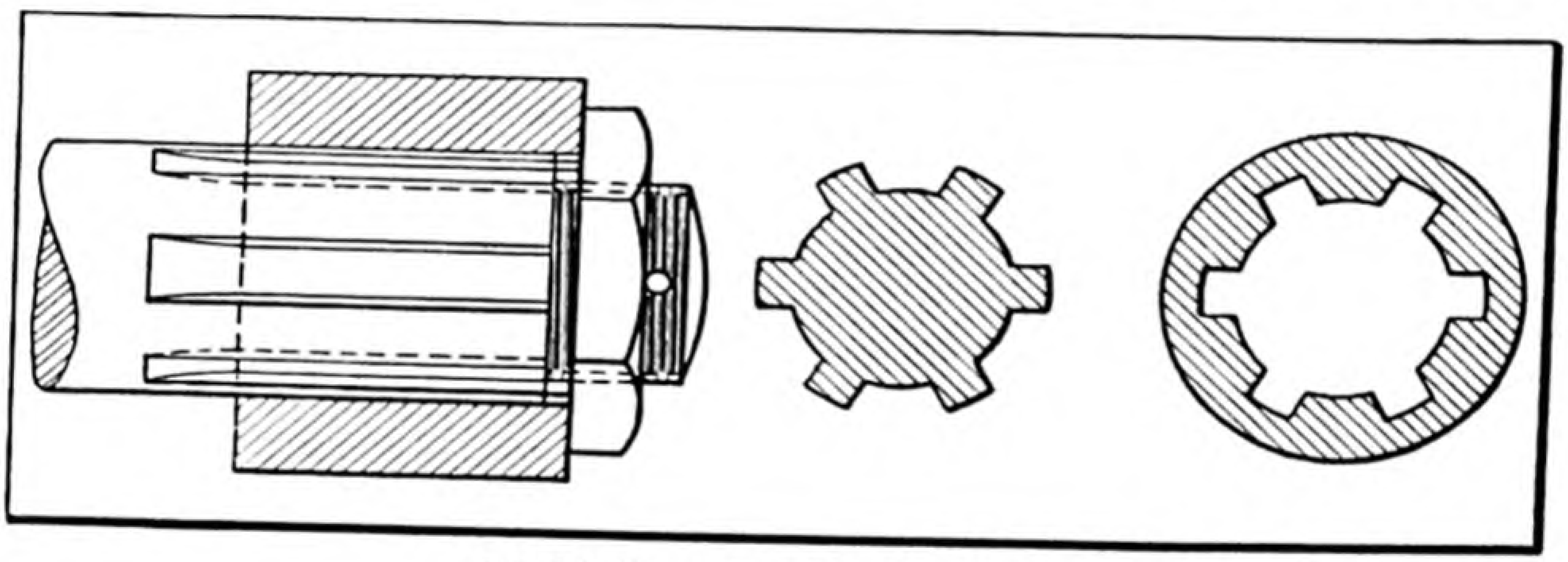
onymous in usage, but the former of these terms is theoretically incorrect. See Helical Gears.

SPIRAL HEAD. A spiral head is an attachment for milling machines, used for indexing or dividing and also in connection with helical milling. See Index Head.

SPIRAL-JAW CLUTCH. A spiral-jaw clutch is a positive clutch in which the tops of the tooth surfaces are helicoidal, the front of the tooth being flat and in the plane of the axis of the clutch. Clutches of this type can only transmit motion in one direction, and are, therefore, known as right- and left-hand.

SPLICING ROPE. See Rope Splicing.

SPLINE. When the hub of a gear or other part must be free to slide axially along its shaft, but rotate with the shaft, a *feather* or *spline* is used. This is simply a form of key, and is either fixed to the shaft or to the hub.



Multiple-spline Shaft Fitting

For instance, in some cases, the feather is sunk into the shaft like an ordinary key, but it is longer than the hub to allow for axial movement. Small splines are often dovetailed into the shaft, whereas larger ones are sometimes held in place by countersunk screws. What corresponds to splines or keys are formed on shafts by milling or hobbing a series of equally-spaced grooves along the shaft, as shown by the illustration. This is known as a *multiple-spline fitting* and is employed on the transmission shafts of automobiles, etc. A fitting of this kind may be either permanent or sliding.

SPONGINESS. Sponginess in castings is due to the formation of gas bubbles in iron at the instant of solidification. In all ordinary cases, this is due to an improper mixture of iron. However, if the casting is very thick at one place, but otherwise thin, it will be impossible to obtain a mixture which will have satisfactory properties for general work and not be spongy at the points of extraordinary thickness.

SPONTANEOUS COMBUSTION. Spontaneous combustion or spontaneous ignition is a condition whereby a material ignites without having its temperature increased by applying heat from an external source. Coal, when stored in large quantities, is likely to ignite in this manner. Other substances that, under the right conditions, have been known to generate sufficient heat to cause spontaneous ignition are coke, lampblack, sawdust, charcoal, oily rags, cotton, flax, hemp, wool, oils, metallic powders, and dust of various kinds. Boiled linseed oil is the most dangerous of oils commonly used in industrial plants. Animal oils have but slight tendency toward spontaneous ignition, as compared with some of the vegetable oils which readily combine with the oxygen of the air. Mineral oils are not considered dangerous in this respect. The spontaneous ignition of oil-soaked rags or waste which has been left in a warm room or in the sun is among the more common occurrences of this kind. In this case ignition is caused by the rapid oxidation of the oil spread out over the large surface afforded by the threads in the waste or the folds of the cloth. As the result of this rapid oxidation, the temperature finally rises high enough to cause ignition. See Coal Storage.

"SPOTTER" FOR FINISHING MACHINE SURFACES. See under Scraping Machine Parts.

SPOT WELDING. For a number of years, electric welding was confined to the butt-welding of rods, tubes, etc., and later the spot welding of flat stock by means of isolated welds of a limited area was developed. One method of making a spot-weld is to use pointed copper dies or electrodes, which are brought into contact with the work which is welded by the passage of a large volume of low-voltage current. Another method is to raise projections above the plane surface of the parts to be welded, which serve to concentrate or localize the current in order to heat the metal to the welding point; and a still further development consists in raising ridges above the plane surfaces, which, when crossed by corresponding ridges, give the same practical results as the raised points, with the additional advantage of ease in assembling the parts prior to welding.

SPRAYING PROCESS OF METAL-COATING. See Metal-coating by Spraying Process.

SPRING BRASS. This is a brass containing about 66 per cent of copper and 33 per cent of zinc with a small percentage (not exceeding 1.5 per cent) of tin.

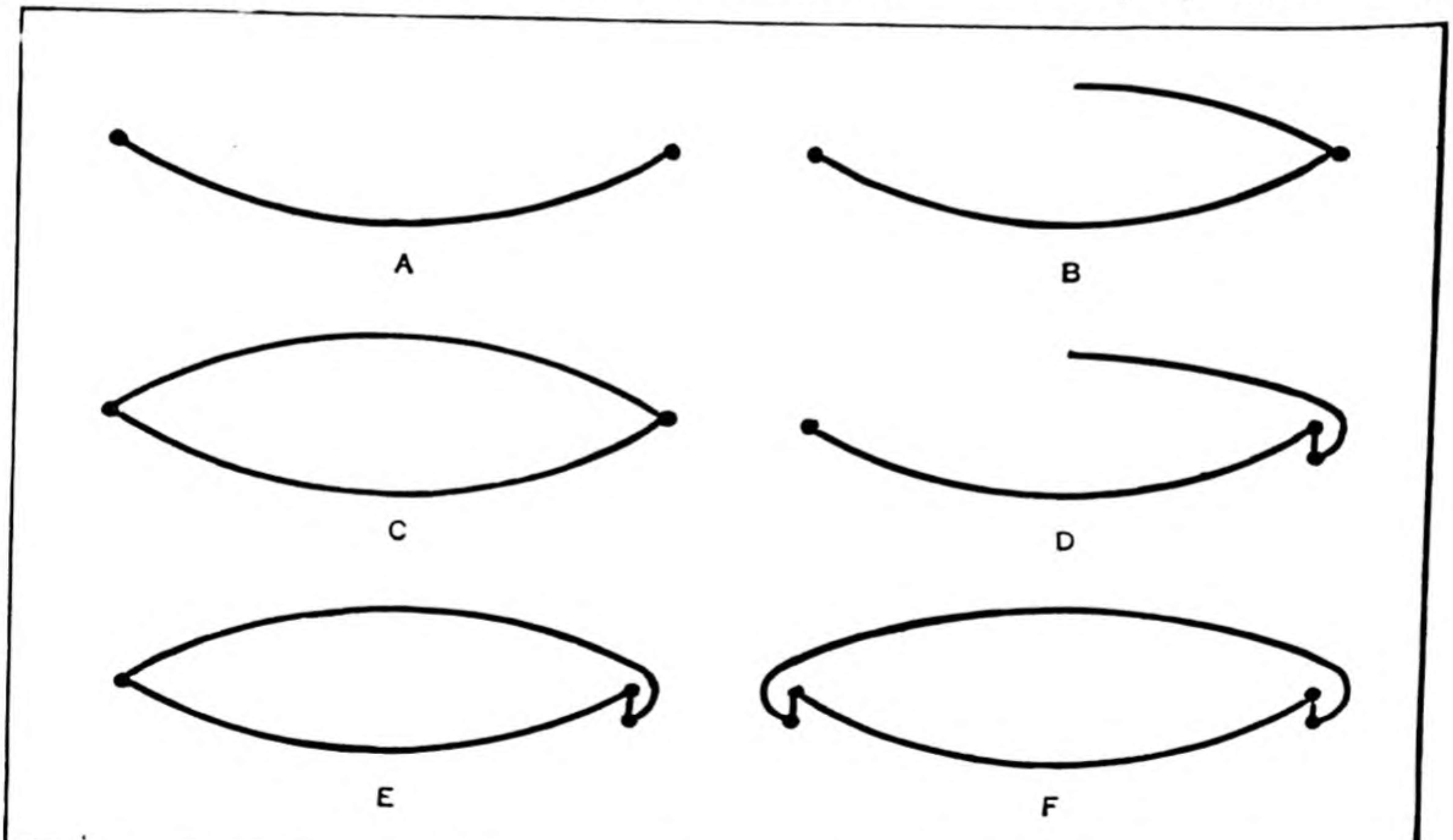
SPRING CALIPER. A spring caliper is a measuring tool used by machinists. The two legs of a spring caliper are joined by a spring (instead of a riveted joint) in such a manner that the bent ends are normally held

apart, while a screw and nut are provided for forcing the measuring points together. Sometimes the nut is split so as to permit of rapid adjustment to an approximate dimension, after which the nut is closed and an accurate adjustment made by turning it on the screw.

SPRING COTTER. A spring cotter, also known as split cotter and split pin, is a piece of wire bent double so as to form an eye at one end, and used for inserting in a hole drilled through a stud or shaft for retaining a nut or some other member. The wire is approximately semi-circular in cross-sections. When inserted in the hole, the outer ends of the cotter are spread apart to retain it in place. Strictly speaking, a spring cotter is a cotter made from spring steel wire, so that when it is bent over on itself it retains enough springing action at the ends, so that these tend to come apart and thereby bind or hold firmly in the hole into which the cotter is inserted.

SPRING PLUNGER. This is a plunger actuated by a helical spring so that the plunger will always occupy a certain position except when pulled back by the hand or by some mechanical means.

SPRINGS. The three principal types of springs are: 1. Flat springs. 2. Spiral springs. 3. Helical or coil springs. The *leaf spring* is simply



Different Types of Leaf-springs

built up from a number of flat springs of uniform rectangular cross-section. By making successive leaves shorter than each preceding leaf, the spring becomes a modification of a beam of uniform strength. These leaf springs are frequently so arranged that they are supported at both ends, having the

load applied in the center. They are then generally curved, so that the load, when applied, tends to straighten them.

Elliptic Springs. — The S. A. E. standard nomenclature for six classes of leaf springs is as follows (see diagrams): Half elliptic spring, *A*; three-quarter elliptic spring *B*, consisting of quarter elliptic on top and half elliptic on bottom — joined at one end by a bolt; elliptic spring *C* consisting of half elliptic on top and half elliptic on bottom — joined at both ends by bolts; three-quarter scroll elliptic spring *D* consisting of quarter scroll on top and half elliptic on bottom — joined at one end by a shackle; scroll elliptic spring *E* (one end), consisting of scroll at one end on top, and half elliptic on bottom — joined at one end by a bolt and at the other by a shackle; scroll elliptic spring *F* (both ends) consisting of scroll elliptic at both ends on top, and half elliptic on bottom — joined at both ends by shackles.

Spiral Spring. — This type is wound in the form of a spiral, the most familiar use of this spring being in watches and clocks. Spiral springs are employed where an angular movement is to be caused by the spring.

Helical or Coil Springs. — Springs of this class are sometimes, although incorrectly, termed spiral springs. Helical springs are wound into a coil from round, square, or rectangular shaped wire or bars, the circular shape of wire being the most common. The *conical* or *helico-spiral* coil spring is a form which is often used on pump valves. Its main advantage as compared with an ordinary coil spring is that it does not easily buckle sidewise. A conical spring also has the advantage that if successive coils are enough smaller than those preceding them, it will, upon compression, close up flat between the constraining surfaces.

SPRINGS, COILING. The method employed for spring winding ordinarily depends upon the number of springs required and, to some extent, upon their form. When a comparatively small number of springs are needed in connection with repair work, etc., it is common practice to wind them in a lathe, whereas, when springs are manufactured in large quantities, special coiling machines are employed. When springs are wound in a lathe, the wire is coiled about an arbor the diameter of which should be determined by trial. Usually the arbor diameter should be about $\frac{7}{8}$ of the required inside spring diameter. The arbor may be mounted between the centers or, in the case of short springs, be held in a chuck. Both extension or closed springs and compression or open springs may be wound in this way. For springs made of wire $\frac{1}{16}$ inch or less in diameter, the speed lathe is commonly used, whereas, for larger wire, it is preferable to use an engine lathe and drive through the back-gearing.

Some means must be provided in any case for subjecting the wire to sufficient tension while winding, to coil it tightly about the arbor. When winding a compression spring, the wire should also be traversed in the direc-

tion of the arbor, so that coils of uniform pitch will be formed; similarly, when winding an extension or " tension " spring, the feeding of the wire should be such that all of the coils will be close together, there being preferably a slight initial tension between the coils. Different forms of tools are used for obtaining the necessary tension on the wire and spacing of the coils while winding. In some cases, the tool is held rigidly in the lathe toolpost and the wire passes through a hole or slot so arranged that the friction and tension may be regulated. The spacing or pitch of the coils can be varied by gearing the lathe the same as for screw cutting, in order to give the carriage a traversing movement while winding the spring. For instance, if a compression spring were required having six coils to the inch, the lathe would be geared for cutting six threads per inch, the result being that, as the carriage moves along, the wire is coiled around the arbor at approximately the same pitch. There is another type of spring winder which is held by hand while the spring is being wound about the arbor, and the tool itself regulates the coil spacing.

SPRINGS, COILING MACHINES. The coiling of springs made in quantities is accomplished either by a standard spring-coiling machine, which may be adjusted to suit coil springs of various dimensions, or if the quantity of a particular type of spring desired warrants it by a special machine which coils, cuts, and hooks the spring in a single operation. Such a machine necessarily has a very limited range, and is found in automobile plants more often than in shops making springs for the trade in general. Standard spring-coiling machines may be classified as continuous coiling machines and coiling and cutting machines. In one machine of the latter type, designed for handling heavy wire, the length of the wire is controlled by the movement of a segment or by gears. The pitch may be automatically controlled so as to square the ends of the springs. This type of machine is used for extension springs as well as for compression springs. Conical and barrel shaped springs as well as springs of constant diameter and varying pitch also come within its scope. In the special machines, as in those for general manufacture, the operations consist of first straightening the wire by drawing it through a groove or rollers, and then coiling it by making it follow the course directed by external rollers or by a combination of external rollers and an internal mandrel. In the coiling operation, the spring wire is automatically tested for uniformity, since hard spots in the wire will be indicated by a bumpy or uneven surface on the coiled spring.

SPRINGS, DEFINITIONS. The following definitions have been accepted as standard for leaf springs by the Society of Automotive Engineers. They are intended primarily to apply to the conventional semi-elliptical

type of automotive spring, but should be applied also to unconventional types if practicable.

Spring Height. — The normal distance from a line through the centers of the spring eyes to the face of the axle spring seat at its center. The *load height* is measured with the spring under its rated load.

Clearance. — The maximum distance the spring can deflect from a given position. The *load clearance* is measured from the rated load position of the spring.

Opening. — The normal distance from a line through the centers of the spring eyes to the face of the main leaf in line with the center of the spring seat.

Length. — The distance between the centers of the spring eyes. The *load length* is measured with the spring under the rated load.

Flexibility. — The number of pounds required to deflect the spring 1 inch measured over the range of from 75 to 125 per cent of the rated load.

Deflection. — The travel, in inches, of the spring under the application of a specified load in pounds.

SPRINGS, DIAMETERS. A helical or coil spring should have an outside diameter equal to from five to eight times the diameter of wire or bar from which the spring is made; under no circumstances should the outside diameter be made less than four times the diameter of the wire. The effective number of coils in a compression spring may be considered as two less than the actual number, owing to the squared ends of the spring.

SPRINGS, FACTOR OF SAFETY. When a spring acts only occasionally it can be safely designed to carry a load which causes a fiber stress nearly equal to the elastic limit of the spring, but, when the compressions or extensions are frequent, a larger factor of safety must be used. A valve spring in an automobile motor, for example, which operates, say, 200 times a minute, should have a factor of safety of at least 4. In other words, a spring, which ordinarily could be designed for a torsional stress of 100,000 pounds per square inch, should be designed to work at a stress not over 25,000 pounds per square inch when used in service of the kind mentioned. High-class springs, such as valve springs, should have the ends squared and ground at right angles to their axis; the outside diameter should be at least one third of the length, and it should be supported its entire length, unless it is very short, in order to prevent buckling, which introduces bending and twisting strains. High-class valve springs when placed on end on a flat plate should not vary more than ½ degree from the perpendicular.

SPRINGS, MONEL METAL. For springs which are exposed to dampness or chemicals that cause them to rust and corrode, monel metal has been used satisfactorily. This metal has a torsional strength of 80,000 pounds

per square inch, a torsional modulus of 9,250,000, a tensile strength of 135,-000 pounds per square inch, and a tensional modulus of 25,000,000. The safe working stress in torsion for monel metal in cases where fatigue is not a factor is said to be 70,000 pounds per square inch. In cases where fatigue is a factor and it is desired that the spring shall operate 2,000,000 times without fracture, a safe working stress in torsion of only 30,000 pounds per square inch should be employed.

SPRINGS, PHOSPHOR-BRONZE. Brass and phosphor-bronze should be used for springs that must resist moisture. These springs are more expensive than steel springs, both on account of the higher cost of the material, and because the permissible stress is less, thus making larger sizes of these springs necessary for the same capacity. If a spring of a material other than steel is desired, phosphor-bronze is usually specified. If the mixture is right, such a spring cannot be surpassed by anything except steel. When difficulties are met with in the use of phosphor-bronze springs, it is advisable to ascertain whether the troubles are not caused by the absence of the necessary amount of tin, or the presence of too much zinc. A phosphor-bronze wire intended primarily for springs has the following composition (S. A. E. Specification No. 81); Tin, 4 to 6 per cent; phosphorous, 0.03 to 0.4 per cent; zinc, maximum, 0.2 per cent; iron, maximum, 0.1 per cent; lead, maximum, 0.1 per cent; copper, the remainder.

SPRINGS, SAFE LOAD AND SIZE. The formulas which follow are for calculating the strength and the maximum safe deflection of any plain coil spring. Formulas for the safe load and deflection have also been transposed for determining the size of wire or the mean radius of a spring for a given strength. In these formulas, P = safe load, in pounds; d = diameter of wire, in inches; r = mean radius of coils; f = deflection, in inches, for load P; N = number of active coils; G = modulus of elasticity (torsional); and S = safe shearing stress, in pounds per square inch.

The formulas are as follows:

$$P = \frac{0.1963\, d^3 S}{r} \qquad f = \frac{64\, N r^3 P}{d^4 G}$$

$$d = \sqrt[3]{\frac{Pr}{0.1963\, S}} \qquad r = \frac{0.1963\, d^3 S}{P}$$

In using these formulas, the values for S and G will vary for different classes and grades of spring wire. The values for average grades follow: For spring brass wire, S equals 30,000 and G equals 6,000,000; for spring steel (tempered), S equals 60,000 and G equals 12,000,000; for music wire, S equals 80,000 and G equals 12,000,000.

SPRING STEELS. When ordinary carbon steel is used for springs, the carbon content should be about 1 per cent and the steel should be comparatively free from phosphorous and sulphur. The S. A. E. steel No. 1095 has been used quite generally for springs. The steel contains a carbon range of 0.90–1.05; a manganese range of 0.25–0.50; a maximum phosphorous content of 0.04; and a maximum sulphur content of 0.05. The heat-treatment of springs made from this steel varies more or less, but for small springs the following is recommended: After shaping or coiling, heat to from 1400 to 1450 degrees F.; quench in oil; draw to from 400 to 900 degrees F., according to the degree of temper desired, and cool slowly.

Alloy steels are now used for many springs. Silico-manganese steel has been standardized by usage, particularly as a spring steel. A typical analysis is as follows: Carbon, 0.50 to 0.60 per cent; manganese, 0.60 to 0.90 per cent; phosphorous, not over 0.045 per cent; sulphur, not over 0.045 per cent; and silicon, from 1.80 to 2.20 per cent. This steel must be heat-treated and the following procedure is recommended: Heat from 1500 to 1650 degrees F.; quench in oil; draw to required hardness and tests. A chromium vanadium steel suitable for springs contains from 0.45 to 0.55 carbon; from 0.50 to 0.80 manganese; from 0.80 to 1.10 chromium; 0.18 vanadium (desired) 0.15 minimum, and a maximum of 0.04 phosphorous, and the same maximum sulphur content. For small springs, music wire is used to a great extent and is the best material obtainable for this purpose. It is especially recommended for devices where the spring is compressed frequently and suddenly.

Spring-tempered and Annealed Wire. — In general, steel wire springs may be divided into two classes — those that are coiled from spring tempered wire and given no subsequent heat-treatment (unless it be a slight draw, which partially removes the internal strains produced by cold working) and those that are coiled from annealed wire and afterward given a complete thermal treatment to impart the proper spring temper. The first method is obviously the cheaper, and hence is used for the majority of machine springs. The latter method, though more expensive, permits better control of the final state of the steel, and is used on many of the more expensive engine valve springs as well as on practically all springs used in measuring instruments. In both classes of springs the methods of manufacture with the exception of the heat-treatment, are almost identical.

SPRINKLER SYSTEMS. The action of an ordinary automatic sprinkler is as follows: A soldered link holds a cap or button securely in place in the water-way of the sprinkler to prevent the flow of water. When a fire occurs under or near a sprinkler, the solder melts, the link is released and water pressure expels the cap. This permits a clear, unobstructed water-way through the sprinkler head. When the released water reaches a metal de-

flector at the top of the sprinkler, its stream is broken up and diffused. At a pressure of five pounds, one sprinkler will wet effectively approximately one hundred square feet of floor area.

Dry-pipe Type. — When continuous heating of buildings at all times, including idle periods, is not feasible, a dry-pipe automatic sprinkler system is often installed. In this type, air replaces water in the pipes. It is under sufficient pressure to keep closed a device known as a dry-pipe valve. In the event of fire, the air escapes through sprinklers which are opened in the usual manner, namely by the action of heat upon their soldered links. When the air pressure is decreased sufficiently the dry-pipe valve opens and allows water to flow through the pipes. The action is then similar to that of an ordinary automatic sprinkler system.

SPROCKET. A sprocket or chain sprocket is a toothed disk or wheel used in connection with chain drives. The chain engages the teeth on the periphery of the driving and driven sprockets, thus transmitting motion from one to the other. The diagram Fig. 1 shows a method of laying out the Society of Automotive Engineers standard roller-chain sprocket tooth form. In the following formulas used for obtaining the dimensions of this layout P = pitch of chain; D = nominal roller diameter; and T = number of sprocket teeth.

$$C = \frac{1.005\,D + 0.003 \text{ in.}}{2} \qquad A = 35^\circ - \frac{120^\circ}{T}$$

$$J = 0.8\,D \sin\left(35^\circ - \frac{120^\circ}{T}\right) \qquad K = 0.8\,D \cos\left(35^\circ - \frac{120^\circ}{T}\right)$$

$$E = 0.8\,D + C \qquad G = 1.24\,D$$

$$F = 0.8\,D \cos\left(18^\circ - \frac{56^\circ}{T}\right) + 1.24\,D \cos\left(17^\circ - \frac{64^\circ}{T}\right) - E$$

$$H = \sqrt{\left[F^2 - \left(G - \frac{P}{2}\right)^2\right]}.$$ When $\frac{P}{2}$ is greater than G, then $H = F$

$$\text{Outside diameter} = P \cot \frac{180^\circ}{T} + 2H$$

$$B = 18^\circ - \frac{56^\circ}{T} = \text{working arc}$$

Connect the two arcs F and E by a common tangent, thus completing the tooth form. In making the alternate layout, Fig. 2, the formulas given

for Fig. 1 are used for dimensions C, E, F, H and the outside diameter. In addition

$$N = 0.8\ D \sin\left(35^\circ + \frac{60^\circ}{T}\right) \qquad M = 0.8\ D \cos\left(35^\circ + \frac{60^\circ}{T}\right)$$

$$V = 1.24\ D \sin \frac{180^\circ}{T} \qquad W = 1.24\ D \cos \frac{180^\circ}{T}$$

$$S = \frac{P}{2} \cos \frac{180^\circ}{T} + F \sin \frac{180^\circ}{T} \qquad G = 1.24\ D$$

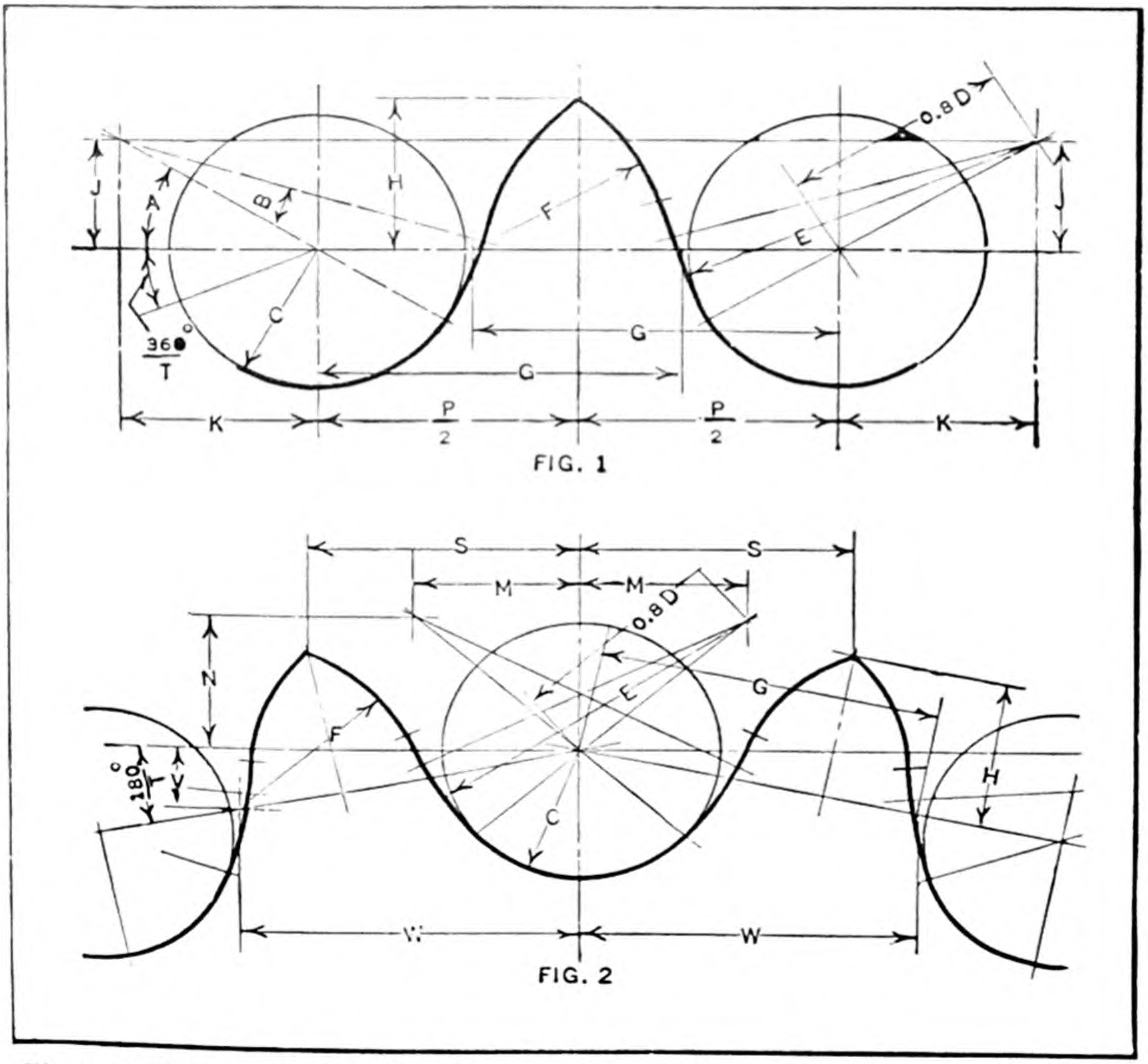


Fig. 1. Roller-chain Sprocket Tooth-form; Fig. 2. Alternate Layout of Sprocket Tooth

The width of the sprocket tooth equals 0.93 times the chain width or roller length minus 0.006. The plus and minus tolerance for width equals 0.01 times chain width plus 0.002. The sides of the upper part of the tooth are rounded to provide sidewise clearance. The radius of these clearance arcs,

which are tangent to the sides and intersect the top, equals 0.43 times pitch, and the centers of these radii are on a line 0.3 times pitch below the top of the tooth. The minimum diameter of roller-chain sprocket blanks is found as follows: Add 0.6 to the cotangent of 180 divided by the number of teeth, and multiply by the pitch of the chain.

SPROCKET ADJUSTABLE RADIALLY. Sprockets of the adjustable type have teeth that may be adjusted radially from time to time to compensate for wear and consequent elongation of chain links. After the chain has elongated beyond a correct fit on the sprocket, nuts are released and eccentric blocks readjusted so as to expand the teeth to the next larger pitch diameter provided for. As a rule, adjustments are not required often.

SPROCKET, GAP TYPE. This is a type of sprocket used for link-belting and employed in cases where the reverse side of the chain runs against the sprocket. When the chain is fitted with some attachment for specific purposes and a reverse bend is required, the sprocket must be provided with a gap or gaps to allow the attachment to pass.

SPROCKETS, LINK-CHAIN. The pitch diameter of a sprocket (especially sprockets having a small number of teeth) must not be figured in the same way as that of spur gear diameter based on the circular pitch. For a sprocket, the pitch length of the chain links must be considered as a chord, whereas the circular pitch of a gear is measured along an arc.

$$\text{Pitch diameter of sprocket} = \frac{\text{Pitch of chain}}{\sin\,(180 \text{ degrees} \div N)}$$

Assume that it is required to find the pitch diameter of a 10-tooth sprocket for No. 42 steel chain, the pitch of which is 1.375 inches. Then

$$\text{Pitch diameter} = \frac{1.375}{\sin\,(180 \text{ degrees} \div 10)} = 4.4498 \text{ inches.}$$

If this sprocket is to be a driver, the pitch diameter calculated should be increased a small amount, and if it is to be driven, the pitch diameter should be reduced a small amount.

If the pitch of the chain and the pitch of the sprocket teeth were equal, the sprockets free from imperfections and always true to size, and the chains exactly uniform in pitch and constant in their original length, it would not be necessary to depart from the calculated pitch diameters of driving and driven sprockets. However, these ideal conditions never exist in actual practice. Sprockets are molded in sand without any finishing cut being taken on the rims, and so there are variations in diameter and imperfections in the teeth. Furthermore, chains become longer due to wear at the joints, even under the best of treatment.

By increasing the pitch of the *driving sprocket*, the detrimental effects due to wear of the sprocket, elongation of the chain, irregularities in molding, etc., are reduced to the minimum. The pitch diameter of the sprocket would be increased approximately $\frac{1}{16}$ inch for the chains in most common use. With small chains, say No. 25 and smaller, the amount would be less, and with large chains, say No. 62 and over, the amount would be greater. Some consideration must be given to the molding of the castings; for instance, a carefully machine-molded sprocket will come more accurately to the size of the pattern than one carelessly molded by hand; consequently, the accurately molded sprocket will admit of a larger oversize allowance in making the pattern, than one that is carelessly molded. It must also be borne in mind that castings usually come larger than the intended size rather than smaller, regardless of the care taken in molding.

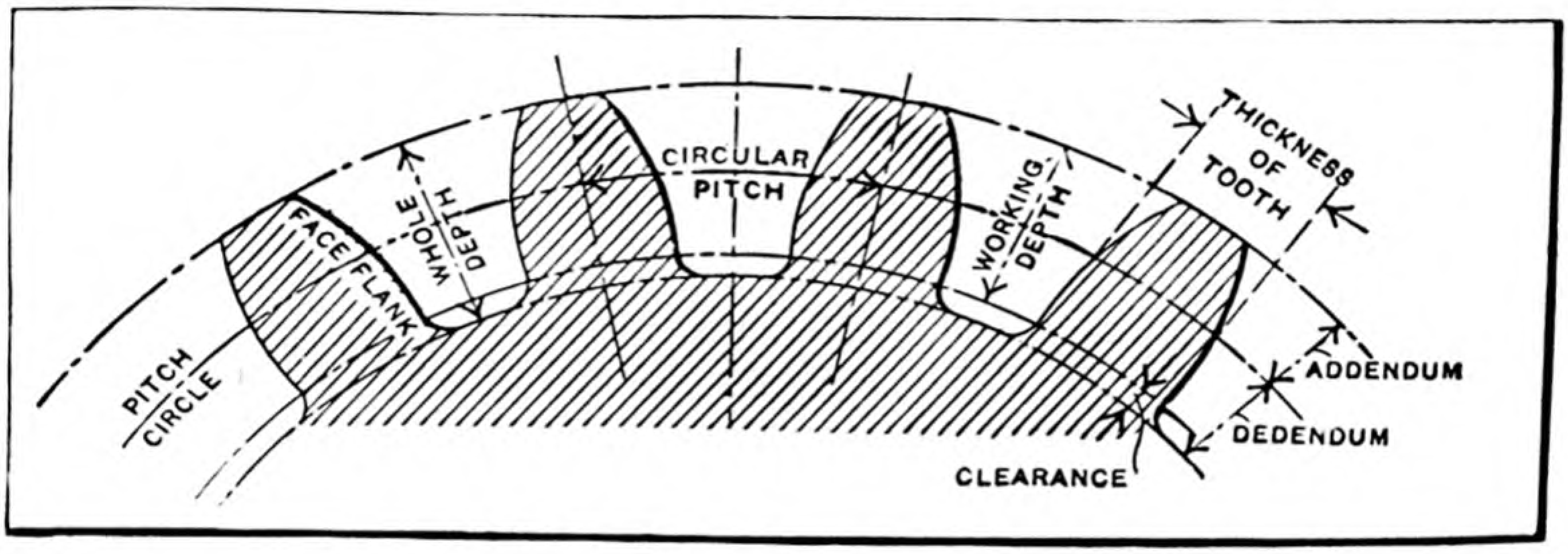
The amount that the pitch diameter should be reduced on the *driven sprocket* should be only enough to take care of variations in the diameter of castings. With good foundry practice, the amount should not be more than $\frac{1}{32}$ inch, while under less favorable conditions it might be well to allow $\frac{1}{16}$ inch.

SPRUE ON DROP-FORGING. Drop-forgings ordinarily are made complete while still a part of the bar of stock. To hold the forging while being worked, a *sprue* must be provided. The sprue is the connecting link between the bar of rough steel and the forging. To form the sprue, a channel is cut from the front end of the impression to the edge of the die-block. The size of the sprue should be governed by the weight of the forging, and in all cases it should be no heavier than is necessary to support the forging while being worked and trimmed. The *gate* is an opening in the front of the die to receive the bar stock.

SPUR GEARING. The type of toothed gearing in which the teeth are formed on the cylindrical surface of the gear blank and are parallel to the axis of rotation of the gear, is known as "spur" gearing. The pitch circles of two spur gears in mesh (which are, of course, imaginary circles), always intersect the common center-line at the point where the line of action crosses this center-line. The term *pitch diameter* as ordinarily applied to gearing means that diameter obtained by dividing the number of teeth by the diametral pitch; both the pitch diameter and the pressure angle, as these terms are ordinarily applied, relate to the diameter and angle corresponding to standard center-to-center distances. The *root diameter* of a gear is the diameter measured at the bottom or roots of the teeth. The *diametral pitch* of a gear is the number of teeth for each inch of pitch diameter, and is found by dividing the number of teeth by the pitch diameter. The *circular pitch* is the distance from the center of one tooth to the center of the next along

the pitch circle. (See diagram.) The *chordal pitch* is the distance from the center (on the pitch circle) of one tooth to the center of the next, measured along a straight line. The *thickness* of the tooth is generally understood to be the thickness at the pitch circle.

The *chordal thickness* of the tooth is the thickness at the pitch circle measured along a straight line or chord. The *addendum* of a gear tooth is the distance from the pitch circle to the top of the tooth. The *dedendum*



Spur Gear Tooth Parts

of a gear tooth is the distance from the pitch circle to the root of the tooth. The *working depth* is the depth to which the teeth in a meshing gear enter into the spaces between the teeth.

The *clearance* is the amount by which the tooth space is cut deeper than the working depth.

The *face* of the tooth is that part of the tooth curve that is between the outside circumference and the pitch circle.

The *flank* of the tooth is that part of the working depth of the tooth which comes inside of the pitch circle.

SPUR GEAR POWER-TRANSMITTING CAPACITY. When it is required to know the diametral pitch for transmitting a given horsepower, this may be determined directly by the following formula, based upon the well-known Lewis formula:

$$P = \sqrt{\frac{S_s A V Y \pi}{H \times 55 \times (600 + V)}} \qquad (1)$$

in which

P = diametral pitch; S_s = allowable static unit stress or the stress at "zero velocity" = 8000 for accurately cut cast-iron gears, 15,000 for steel containing about 0.30 per cent carbon, 25,000 for steel containing about 0.50 per cent carbon, 9000 for semi-steel, 5000 for rawhide, bakelite, formica, and condensite, and 12,000 for phosphor-bronze; A = a factor which is

usually 3 or 4 for cut gears, the assumption being that the face width is to equal 3 or 4 times the circular pitch, which is the general practice; V = pitch-line velocity in feet per minute — preferably limited for average conditions to about 1200 feet per minute for cut spur gears of ordinary quality to avoid excessive noise; Y = Lewis formula outline factor for a given diametral pitch and pressure angle (see table of factors in connection with Lewis formula, MACHINERY'S HANDBOOK); H = horsepower.

When the diametral pitch and velocity are known, the horsepower that can be transmitted by a gear of given material may be determined by the following formula, which is also derived from the Lewis formula:

$$H = \frac{S_s VFY}{P \times 55 \times (600 + V)} \qquad (2)$$

in which F = face width in inches. The notation otherwise is the same as for Formula (1).

SPUR GEAR, "TWISTED." See Twisted Spur Gear.

SQUARE ENGINE. This is a term sometimes employed to describe an engine that has a stroke equal to the diameter of the piston. For example, an engine having an 8-inch diameter and 8-inch stroke would be an 8-inch square engine.

SQUARE FILE. This style of file either tapers from the middle toward the point or is made of uniform cross-section throughout. The taper square file has double-cut, bastard teeth, and is extensively used in machine shops generally, principally for enlarging apertures of a square or rectangular shape. The blunt form also has double-cut bastard teeth and is employed by engine builders and in the shops of railroads, ship-yards, etc., for the rougher work in finishing or enlarging mortises, keyways, or splines, especially when of considerable length.

SQUARE GRINDING BY ROTARY METHOD. The square ends of transmission shafts and similar parts may be ground by rotating the work continuously as in cylindrical grinding, provided an oscillating attachment is employed similar to the type used for cam grinding in automotive plants. Such an attachment may be adapted to square grinding by equipping it with a master cam which causes the work to swing relative to the grinding wheel so that the working face of the latter generates flat surfaces on the square section. These flat surfaces forming the square are connected by small corner arcs. This method has been used to increase production as compared with the older method of using cup wheels and a hand-operated indexing fixture.

SQUARE HOLE DRILLS. See Drills, Angular Hole.

SQUARE-JAW CLUTCH. This is a positive clutch provided with teeth having perpendicular or square sides, so that, when engaged, the clutch will drive in either direction. Clutches of this type cannot be engaged and disengaged readily unless stationary or revolving slowly.

SQUARE MEASURE. 1 square mile = 640 acres = 6400 square chains; 1 acre = 10 square chains = 4840 square yards = 43,560 square feet; 1 square chain = 16 square rods = 484 square yards = 4356 square feet; 1 square rod = 30.25 square yards = 272.25 square feet = 625 square links; 1 square yard = 9 square feet; 1 square foot = 144 square inches. An acre is equal to a square, the side of which is 208.7 feet.

SQUARE ROOT. The square root of a given number or quantity, is that number or quantity which, when multiplied by itself, will give a product equal to the given number. If the given number is 81, the square root is 9, because $9 \times 9 = 81$. The sign $\sqrt{\ }$ indicates that the square root is to be extracted. Thus $\sqrt{81} = 9$.

SQUARE THREAD. The square thread is so named because the section is square, the depth, in the case of a screw, being equal to the width or one-half the pitch. The thread groove in a square-threaded nut is made a little greater than one-half the pitch in order to provide a slight clearance for the screw; hence, the tools used for threading square-threaded taps are a little less in width at the point than one-half the pitch. The pitch of a square thread is usually twice the pitch of a U. S. standard thread of corresponding diameter. The square thread has been superseded quite largely by the acme form which has several advantages. See Acme Thread.

SQUARING SHEARS. Squaring shears, for cutting sheet tin, iron, brass, copper, aluminum, etc., are of the foot-treadle or power-driven types. They have one fixed cutting blade, which is usually the lower blade and attached to the bed of the machine, and one movable blade attached to the cross-head or gate which is guided in vertical slides. Side gages are provided that can be bolted square with the cutting blades for guiding the sheet metal for squaring operations, and long bed gages that can be bolted parallel to, or at an angle to the cutting blades, in the front or in the rear of the machine, for guiding the cutting of the metal to the lengths required. On power squaring shears the stroke of the cross-head is controlled by means of an automatic clutch. The clutch is tripped with a depression of a foot-treadle, and unless the treadle is kept depressed the motion of the cross-head will stop automatically at its highest point. When the side housings or frame of a squaring shear is shaped with a throat or gap so as to permit the handling of sheets of a width greater than the width of the machine, the shears are known as *gap squaring shears*.

SQUEEZER. The squeezer to which the hot rolls of iron are taken from the puddling furnace, in producing wrought iron, consists of a horizontal corrugated drum which revolves eccentrically within a housing. Between the drum and the housing wall, which is open at one side, there is a channel which is large enough at one end to receive one of the puddled balls. This channel tapers in its passage around the drum so as to flatten the ball gradually into an elongated section of metal. When this flattened metal reappears after its revolution around the drum, it has been freed from much of its original slag.

STAGE. In air compression, the term stage refers to the different steps in which air is compressed in multi-stage compressors, the air being compressed first in one cylinder to a certain pressure and then passed to another cylinder where it is compressed to a higher pressure. It is generally passed through an intercooler between the two cylinders, where it is cooled to its initial temperature before the second stage of compression.

STAGGER-FEED PRESS. A punch press equipped with a stagger feed is so arranged that the punch cuts blanks in a staggered relation to one another, thus reducing waste and utilizing the stock to the greatest extent. Such a feed is especially suitable for the production of such parts as can tops and bottoms and other small shells. The sheet stock is held in a carrier which travels past the reciprocating punch. The stagger feed may be so designed that it is not necessary for the carrier to be returned to the starting point after punching a row of blanks, because the moment the end of a row has been reached the action of the carrier is automatically reversed and the next row may be punched as the carrier returns to the starting point.

STAINLESS IRON. The name " stainless iron " is rather misleading as it relates to a very mild stainless steel which forms the lowest carbon member of a series of steels of continuously varying content which are, in many respects, the counterpart of the series of ordinary carbon steels ranging from " dead soft " to tool steels. Because of its greater softness, stainless iron forges more easily than the harder varieties of stainless material; it works probably as easily as ordinary steel containing about 0.4 per cent carbon and hence may readily be forged, rolled, or drop stamped.

STAINLESS STEEL. The expression " stainless steel " is applied to a low-carbon alloy steel of high chromium content, which possesses to a remarkable degree the property of resisting corrosion. The chromium content of ordinary stainless steel may vary from about 9 to 20 per cent. This steel was originally developed for use in the cutlery trades, because it neither rusts nor tarnishes when in contact with food and many fruit acids; hence the name " stainless." Stainless steels can readily be rolled,

forged, drawn and fabricated and they are made in the form of bars, sheets, plates, structural shapes, wire, and tubing. A steel having about 18 per cent chromium, when unannealed and in the rolled or forged condition, has an ultimate strength of 80,000 to 90,000 pounds per square inch. It can readily be forged at the same temperatures and in the same manner as 0.40 to 0.50 carbon steel, although a somewhat longer heating or soaking in the furnace is advisable. Stainless steel can be welded, either by using an oxy-acetylene torch or the electric arc method, but it will not hammer-weld. Re-annealing after forging or welding is advisable if machining or ductility are required. For thorough annealing, heat the steel to 1500 to 1600 degrees F., soak thoroughly at this temperature and cool slowly in the furnace. Ordinary annealing may be obtained by heating to 1400 to 1500 degrees F. and cooling in still air.

Cutlery Type. — This type of steel contains about 0.28 to 0.38 per cent carbon; chromium, 12.75 to 14.25 per cent; manganese, 0.25 to 0.35 per cent; silicon, 0.15 to 0.30 per cent; sulphur and phosphorus, under 0.030 per cent; and nickel, optional. This steel does not absorb heat readily and in heating for forging it should be "soaked" two or three times as long as ordinary steel and at a temperature of about 1300 degrees F. The forging should be done between a temperature range of 1700 and 2000 degrees F.

This is an air-hardening steel, but it will be somewhat harder if quenched in oil or water. For general applications oil is recommended and a hardening temperature range of 1750 to 1850 degrees F. This steel, when drawn or tempered within a range of from, say, 300 up to 1000 degrees F., has an ultimate tensile strength of 245,000 to 255,000 pounds per square inch.

Turbine Type. — The turbine type of stainless steel is so named because of its use for the blades of steam turbines. The United States Navy specification for a corrosion-resisting turbine blade steel is as follows, the figures representing percentages: Carbon, 0.06 to 0.13; chromium, 11.50 to 13; silicon, under 0.35; manganese, under 0.55; sulphur and phosphorus, each under 0.030; nickel under 0.50; chromium and nickel, under 13. The minimum tensile strength is given as 100,000 pounds per square inch. However, turbine steel when hardened may have an ultimate strength of 200,000 pounds per square inch, and an ultimate strength of from 185,000 to 195,000 pounds per square inch for drawing temperatures up to about 1000 degrees F. The forging range is from about 1600 to 1900 degrees F. Hardening by quenching in oil from a range of 1775 to 1825 degrees F. will give a Brinell hardness from 375 to 425. The hardness will be reduced somewhat by air cooling. To anneal this steel it should be soaked thoroughly at about 1450 degrees F. and allowed to cool either in a furnace or in the air.

Malleable Type. — The so-called malleable stainless steel is a composition which has good forging properties and is similar in this respect to low-carbon steel. It contains (in percentages) carbon, under 0.10; chromium, from 13.50 to 15; silicon, under 0.50; manganese, under 0.20; sulphur and phosphorus, each less than 0.030. A drop forging temperature of 1900 degrees F. is recommended and slow heating is essential. This steel possesses only slight air-hardening properties. Oil quenching from a temperature of 1800 degrees F. will give a Brinell hardness of about 300. The ultimate strength for drawing temperatures up to about 1000 degrees F. ranges from 145,000 to 150,000 pounds per square inch.

Valve Type. — This type of steel is so named because of its use for gas or gasoline engine valves, on account of its resistance against scaling or oxidation at high temperatures. The valve type contains (in percentages) approximately the following composition: Carbon, 0.45 to 0.55; chromium, 8 to 9; silicon, 1.5 to 3; manganese, under 0.50; sulphur and phosphorus, each under 0.030. The silicon content is much higher than for the other stainless steels, which reduces the air-hardening effect and the chance of valve breakage in cooling after exposure to high temperatures. Both forging and hardening temperatures should be about 1900 degrees F., and oil quenching gives a Brinell hardness of 500 or higher. To anneal, cool slowly from 1575 degrees F.

Deep-draw Type. — The deep-drawing stainless steel is very tough and ductile and, consequently, adapted to deep drawing or forming in the cold state in producing parts from sheet stock. The approximate composition (in percentages) follows: Carbon, about 0.15; chromium, 17 to 19; nickel, 7.5 to 9.5; silicon, under 0.50; manganese, under 0.25; sulphur and phosphorus, each under 0.030. The forging range is from 1700 to 2000 degrees F., and a soft ductile condition may be obtained by either cooling in the air or quenching in water from a temperature of about 1900 degrees F. This steel in its softest condition has a tensile strength of about 90,000 pounds per square inch and it has good corrosive resistance.

STAINLESS STEEL CASTINGS. Castings made from stainless steel possess the corrosion-resisting characteristics common to stainless iron and steel in sheet and rolled form. Stainless steel castings are especially adapted for use in the chemical industry for resisting various acids and chemicals, or wherever castings are subjected to unusual corrosion or attacks from injurious elements. Castings of this kind are commonly used for such parts as valve bodies, pipe fittings, stirring devices for chemical apparatus, chemical still bottoms, centrifugal pump impellers for water and corrosive chemicals or liquids, and, owing to corrosive resistance against the action of sea water, for pump bodies, dock sluice gates, etc. Most stainless steel

castings have a chromium content ranging from 13 to 18 per cent. Castings of this kind may be machined readily and fine finishes obtained. The contraction of stainless castings is somewhat greater than that of ordinary steels and is about $\frac{9}{32}$ inch per foot. Very thin flanges and webs should be avoided if possible. Under ordinary conditions, the minimum thickness should be $\frac{3}{8}$ inch, although in special cases thinner sections can be allowed.

One of the most important properties of stainless steel, especially in connection with the chemical industries, is its immunity to attack by nitric acid. Steels of this class also resist oxidation at temperatures of from 1500 to 1800 degrees F. and even higher temperatures, depending upon the percentage of chromium in the alloy. Because of this property, stainless steel castings are especially adapted for certain furnace parts. In this connection, the chrome-iron alloys offer a high degree of immunity to sulphur corrosion. In this respect they are superior to the nickel-chromium-iron compositions in which nickel is the predominating alloying element, because the nickel is rapidly converted into nickel sulphide. This immunity to sulphur corrosion is particularly of importance where furnaces are operated with high sulphur fuel oil or producer gas from high sulphur coals. According to a manufacturer of stainless steel castings there is a marked tendency toward grain growth at temperatures exceeding 1500 degrees F. and when the chromium percentage exceeds 20 per cent, the castings become very brittle and somewhat unreliable as to physical properties. These defects may be minimized by the introduction of a small amount of nickel which is of great benefit for general commercial applications and does not detract greatly from the corrosion-resisting qualities of the alloy; however, even small nickel additions are objectionable for parts subjected to nitric acid. If castings are intended for nitric acid work, the qualities of ductility and machineability are obtained by keeping the carbon content under 0.20 per cent and annealing the casting before machining. Castings containing from 16 to 18 per cent chromium have an ultimate tensile strength, according to a manufacturer, close to 100,000 pounds per square inch, whereas castings of higher chromium content (27 to 30 per cent) have an ultimate tensile strength of 40,000 to 50,000 pounds per square inch.

STAINLESS STEEL, MACHINING. For cutting stainless steel, tools similar to those used for low-carbon or mild steel with similar feeds and speeds are considered suitable. Individual cases may require modifications in this respect, for tearing is sometimes experienced, and some brands of stainless steel are more difficult to machine than others. If trouble arises, it is usually best to reduce the feed first, and if this does not overcome the difficulty, the speed should be reduced until suitable results are obtained. By the use of the electric arc process the gates, risers, fringe and overflow of stainless steel castings can be cut off quickly, with minimum power

requirements and without changing the temper or quality of the casting. By this process, the cuts can also be kept smooth and ready for machining, so that very little grinding is necessary.

STAINLESS STEEL WELDING. In welding of stainless steel, each particular alloy and application of this new rustless metal often presents a distinct welding problem. Some alloys are best welded with gas, some with direct-current and some with alternating-current electric welding equipment. Of the two electric welding methods, that using direct current is generally preferable for the copper-base rustless alloys, while that employing alternating current is better for the chromium and nickel-base alloys.

STANDARD CELL. A primary cell used for obtaining a certain standard value of electromotive force under given conditions is known as a standard cell. To avoid polarization, standard cells are usually connected in series with high resistance, so that only a small current is obtained. Two common types of standard cells are the Clark and the Weston.

STANDARD PRESSURE. This term applied to valves and fittings means that they are suitable for a working steam pressure of 125 pounds per square inch.

STANDARD SCREW THREAD. A standard thread conforms to an adopted standard in regard to the form or contour of the thread itself, and as to the pitches or numbers of threads per inch for different screw diameters. A screw thread having either a modified form or a pitch which is either greater or less for a given screw diameter, than the adopted standard, is special.

STANDARD SECTION. This is a term applied to a structural shape, such as an I-beam, channel, or angle, designated by the makers as "standard." The standard section is generally the minimum section of each group of structural shapes. See Structural Shapes.

STANDARDS OF LENGTH. In 1866, Congress passed a law making legal the meter, the first and only measure of length that has been legalized by the United States Government. In May, 1875, representatives of various countries signed a treaty providing for the establishment and maintenance, at the common expense of the contracting nations, of a "scientific and permanent International Bureau of Weights and Measures, the location of which should be Paris, to be conducted by a general conference for weights and measures, to be composed of the delegates of all the contracting governments." This bureau was empowered to construct and preserve the international standards, to distribute copies to the several

countries, and also to discuss and initiate measures necessary for the determination of the metric system. Thirty-one metric standards were made, and each country contributing to the support of the International Bureau received copies. The distribution was made by lot, the United States receiving Nos. 21 and 27. The international meter adopted by the Bureau was declared, by a formal order of the Secretary of the Treasury in 1893, to be the *fundamental unit of length* in the United States.

The primary standard is deposited at the International Bureau of Weights and Measures near Paris. This platinum-iridium bar has three fine lines at each end; the distance between the middle lines of each end, when the bar is at a temperature of 0 degrees C., is one meter, by definition.

The United States yard is defined by the relation, 1 yard = $\frac{3600}{3937}$ meter. The legal equivalent of the meter for commercial purposes was fixed as 39.37 inches, by law, in July, 1866, and experience having shown that this value was exact within the error of observation, the United States Office of Standard Weights and Measures was, in 1893, authorized to derive the yard from the meter by the use of this relation. The United States prototype meters Nos. 27 and 21 were received from the International Bureau of Weights and Measures in 1889. Meter No. 27, sealed in its metal case, is preserved in a fireproof vault at the Bureau of Standards. No. 21 is occasionally used to verify the secondary or working standards of the Bureau, and, in special cases, where the highest accuracy is required, other meters are compared with it. The Bureau also possesses two other platinum-iridium standards, known as Nos. 4 and 12. The former is divided into millimeters for its entire length, and, in addition, is ruled with a special line to define the yard. For the routine work of testing, use is made of secondary or working standards the values of which are carefully determined by comparison with prototype meter No. 21, from time to time, to detect any possible changes. These working standards include multiples and submultiples of the meter and of the yard. See Light Wave as Length Standard.

STANDARDS OF LENGTH COMPARED. There is an unfortunate difference in the relation between the standards of measurements as defined in the United States and Great Britain, but the difference is so small that it is of no importance in ordinary mechanical work, as it amounts to only 1/363,000 inch in one inch. The difference, however, becomes of importance in the more precise length measurements of science and industry, where accuracy of 1/1,000,000 of an inch or even higher, may be required. The Bureau of Standards, in a publication entitled "A Fundamental Basis for Measurements of Length," by H. W. Bearce, Senior Physicist, published as Scientific Paper No. 535 of the Bureau of Standards, states the matter as follows: "There is at present a slight difference in the

official relation between yards and meters in the United States and in Great Britain. In the United States, the official relation is:

$$\frac{1 \text{ yard}}{1 \text{ meter}} = \frac{3600}{3937}$$

" In Great Britain the official relation is:

$$\frac{1 \text{ yard}}{1 \text{ meter}} = \frac{3600}{3937.0113}$$

" From these relations may be derived the following approximate relations:

1 United States inch = 25.40005 millimeters
1 British inch = 25.39998 millimeters "

In order to avoid these discrepancies, the bureau recommends that the meter be defined in terms of wave lengths of light from cadmium vapor, and that the simple relation of 1 inch equals 25.4 millimeters be adopted universally wherever the English or the metric systems are used. If this relation is adopted as exact, then the corresponding relation, 1 yard equals 0.9144 meter, will also be exact.

STANDARDS OF WEIGHTS AND MEASURES. Originally the Bureau of Standards was mainly a government agency that preserved for comparison and duplication the standards of length and weight (mass.) This function the bureau still retains, in addition to its many other activities. In what is known as the " standard vault " are preserved the national standards of length and weight. Here is a standard meter made in 1797, and a yard made about 1830, as well as standard weights dating back to the early part of the past century. In addition, there are many standards made at a later date. The length and weight comparators are kept in a " constant temperature room," and are used for fundamental comparisons of length and mass under conditions controlled so that the highest precision can be obtained. The standards with which comparisons are made can be kept at a constant temperature within 0.1 degree F. A comparator is also available for standardizing precision steel tapes, such as are used in very accurate surveys. The room in which this work is done can be kept at any temperature from 32 to 110 degrees F. The bureau also coöperates with the state and local authorities for the inspection of trade weights and measures, by annual conferences with the officials engaged in such work, by the distribution of handbooks relating to the technical details of weight and measure inspection work, and by consultation and correspondence.

STANDARD WIRE GAGE. This refers to the standard British wire gage, generally abbreviated S. W. G., legalized in Great Britain by Order

in Council, August 23, 1883. It is also known as the "New British Standard wire gage," abbreviated N. B. S., and as the "British Legal Standard wire gage," and the "Imperial wire gage."

STANDING BALANCE. This is the same as static balance.

STARTING BOXES FOR MOTORS See Motor Starters, and Motor Speed Regulation.

STARTING SWITCHES. Starting switches are lever switches especially arranged for machine starting. They are of two general classes, depending upon whether direct current or alternating current is used. The common method of starting a direct-current machine is to connect a starting resistance in series with the armature, and then, after connection is made to the line, to cut out the resistance step by step as the machine comes up to speed.

When starting synchronous converters from the alternating-current side or when starting alternating-current motors of large capacity which take their current from an individual bank or set of transformers, the starting is accomplished from voltage taps on the transformers. Three-phase machines are usually started from half-voltage taps and six-phase machines from one-third and two-third taps. The starting switches used for the purpose look very like the ordinary spade-handle lever switch, but they are especially arranged for starting purposes; they are always double-throw. The handles are weighted to assist the operator in throwing the switches over quickly. One double-pole switch is used in starting a three-phase machine, the upper contact clips being connected to the half-voltage tap.

STATIC BALANCE. If a circular part, such as a cylindrical drum or pulley, were mounted in bearings in which friction was practically eliminated, and with the axle in a horizontal position, it is evident that if one side were even slightly heavier than the other this unbalanced side would be at the bottom or lowest point possible when the drum or pulley came to a state of rest. If this same part were brought to such a state of balance that it would remain standing when turned about its axis to any position, it would be in *standing* or *static* balance; it does not necessarily follow, however, that this part would be in a balanced state when revolving, although if it has a running balance it will also be balanced statically. See Balancing Methods.

STATIC ELECTRICAL PHENOMENA. The term "static" is applied to certain electrical phenomena other than the flow of electric current along a conductor. Thus, if two bodies between which current would flow are separated from each other by a non-conducting medium, so-called *electro-*

static forces are set up in the medium. If these forces become excessive, the insulating medium, whether solid, liquid, or gaseous, will be punctured, and current will flow, as, for instance, in a lightning stroke. These forces also act directly upon the bodies, attracting them towards each other, or if two bodies are of the same polarity (that is, no current tends to flow between them, but would flow, if it could, to some third body), the static forces would act to repel the bodies from each other. Electro-static strains can be set up in insulation by friction, for instance, by rubbing a hard-rubber rod with cat's fur, and these attractions and repulsion can thus be illustrated.

STATIC PRESSURE. See Blower Pressures.

STATIC TRANSFORMER. See Transformer.

STAYBOLT. A staybolt is a bolt used in boilers and locomotives for supporting or staying the tube sheets. Staybolts are threaded throughout their length and are inserted in tapped holes in the inner and outer sheets. The ends are riveted over to tighten and strengthen the bolt.

STAYBOLT IRON. A wrought iron used for boiler staybolts, made entirely from puddled charcoal iron free from any admixture of iron scrap or steel, having a tensile strength of from 49,000 to 53,000 pounds per square inch.

STAYBOLT STEEL. A steel employed for boiler staybolts, made by the open-hearth process, and having a tensile strength of from 50,000 to 60,000 pounds per square inch.

ST. CROIX RULE. This is a rule employed for finding the board measure of logs, as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet; usually the diameter inside of the bark at the small end is measured.

STEADYRESTS FOR GRINDING. Practically all parts that are ground on centers should be supported by suitable steadyrests or back-rests, as their use will not only obviate chattering, when properly applied, but permit taking deeper cuts with coarser feeds and also increase the "sizing power" of the wheel. In grinding long and slender parts, such supports are indispensable, and, even for work which is short and rigid, steadyrests are desirable to prevent vibration, which increases wheel wear and affects the quality of the ground surface. These supports are fastened to the table of the machine and are equipped with shoes of hardwood or metal which bear against the piece being ground. The number of steadyrests used depends upon the form and diameter of the work. According to a

commonly accepted rule, the distance between each steadyrest should be from six to ten times the diameter of the part being ground. Some recommend the use of as many rests as can conveniently be fixed in position.

STEADYRESTS FOR TURNING. Occasionally long slender shafts, rods, etc., which are to be turned, are so flexible that it is necessary to support them at some point between the lathe centers. An attachment for the lathe known as a " steadyrest," is often used for this purpose. The common form of steadyrest is composed of a frame containing three jaws that can be adjusted in or out radially to suit the diameter of the work. The frame is hinged at one side, thus allowing the upper half to be swung back for inserting or removing work. A *follow-rest* differs from a steadyrest in that it is attached to and travels with the lathe carriage so that the support remains adjacent to the turning tool, which is especially important in turning shafting or other long parts.

STEAM. Steam is water changed to a gaseous form by the application of heat. It may be either *saturated*, *superheated*, *dry* or *wet*. Saturated steam is that which is in the presence of, and at the same temperature as, the water from which it was evaporated. There is always a definite relation between the pressure and temperature in the case of saturated steam. For example, saturated steam evaporated under atmospheric pressure always has a temperature of 212 degrees F. Steam evaporated under a pressure of 5 pounds (gage) has a temperature of 228 degrees F.; under 10 pounds pressure, 240 degrees F.; under 100 pounds, 338 degrees F., and so on. *Superheated steam* is that which has been heated to a temperature above that due to its pressure. Steam is superheated by passing it through pipes or coils exposed to the hot gases from the furnace, after it leaves the steam space of the boiler. Engines and turbines are supplied with superheated steam, under favorable conditions, in order to obtain a higher efficiency. *Dry steam* is that which contains no moisture. It may be either saturated or superheated. *Wet steam* contains more or less moisture in the form of spray; in other ways it does not differ from saturated steam, having the same temperature at different pressures.

Steam Quality. — The percentage of dry steam in steam containing moisture, is called the quality of the steam. For example, if a pound of a given sample of steam contains 0.04 pound of water in the form of spray, and 0.96 pound of dry saturated steam, the quality is said to be 96 per cent. It is very important to know the quality of the steam when testing a boiler for capacity and fuel consumption, as water carried over in the form of spray has no value for the generation of power in a steam engine, or for heating purposes. As the quantity of steam evaporated in a given time is found by weighing the feed water, it is evident that the moisture con-

tained in the steam will appear in the result, unless its percentage is known and the necessary correction made. The proportion of moisture in steam is found by means of a device called a calorimeter, which forms an important part of the equipment used in boiler testing.

STEAMBOAT COAL. This is coal consisting of large pieces which do not pass through screens of $3\frac{1}{2}$-inch mesh.

STEAMBOAT ORIGIN. Although Robert Fulton was not the first man to build a steamboat, the *Clermont*, which he constructed was the first boat that was a commercial success. Much that Fulton accomplished was undoubtedly due to the ideas he obtained from those whose experiments antedated the construction of the *Clermont*. James Rumsey began experimenting as early as 1785, and a year later John Fitch is said to have constructed the first steam-propelled craft which met with any degree of success in America. It was a most clumsy contrivance, however, being propelled by gangs of oars arranged in a frame-work at the sides. The second American steamboat was run by Fitch on the Delaware at Philadelphia in 1787. In the same year Rumsey is said to have built the third boat which operated on the Potomac. The propulsion of this novel craft was accomplished by sucking in water at the bow and expelling it at the stern — a method which has been tried in recent times. In the two following years Fitch built two other steamboats, after which Samuel Morey built a stern-wheeler, which made a trip from Hartford to New York. Fitch, who had been conducting his experiments on the Delaware at Philadelphia, came to New York where he operated the seventh American steamboat.

John Stevens began his work in steam navigation in 1791. In 1798, a steam-propelled vessel was tried on the Passaic River. The New York Legislature was petitioned by Stevens for a monopoly of steam navigation, but the petition was not granted. In 1904 a 68-foot boat, 14 feet wide, fitted with a single-screw propeller, was built by Stevens and in 1805 a twin-screw boat was launched on the North River. The machinery of this boat was afterward placed in a larger boat, the *Phoenix*, which was 103 feet 3 inches long, 16 feet wide, and 6 feet 9 inches deep. While the launching of the *Phoenix* occurred after that of the *Clermont*, if one may judge from models, the lines of Steven's craft were much superior to those of the *Clermont*. The engine also shows greater simplicity. In the spring of 1809, the *Phoenix* made a number of trips between New York and New Brunswick, a distance of 37 miles, in $9\frac{1}{2}$ hours including stops. It was decided to sail the *Phoenix* to the Delaware River by way of the Atlantic and she left New York on June 8, 1809, arriving at Philadelphia on June 17. Thus was accomplished the first sea voyage of a steam-propelled vessel. The *Phoenix* ran as a passenger boat on the Delaware, stopping at Philadelphia,

Bordentown, and Trenton. After running for a number of years over this route the *Phoenix* was wrecked at Trenton in 1814.

The original *Clermont* was built at Charles Brown's shipyard near Corlear's Hook, New York. According to a letter written by Fulton to James Watt, she was 175 feet long, had a beam of 12 feet, and a depth of 8 feet. After making four trips the length was reduced to 150 feet and the width increased to 18 feet. The propulsion was by paddle wheels, 15 feet in diameter, which were placed well forward. These were driven by a single-cylinder condensing engine of the side-lever type, which was imported from England, as the facilities in this country at that time for engine building or similar work were very poor. This engine with its driving mechanism was located amidships, and was uncovered. The cylinder was designed for a working pressure of 20 pounds.

The famous voyage of the original *Clermont* from New York to Albany began on August 17, 1807. Leaving New York at one o'clock in the afternoon, the *Clermont* arrived at the estate of Chancellor Livingston, at 10 o'clock on Tuesday, having traveled 110 miles in 24 hours at an average speed of 4.6 miles per hour. On the remaining 40 miles of the journey to Albany, this speed was increased to 5 miles per hour, making 32 hours the total time for the trip.

STEAM CALORIMETER. This is a device used for determining the percentage of moisture in steam. See Calorimeters.

STEAM COOLING. The steam cooling system for automobile engines is really a water cooling system in which the water is permitted to boil, the radiator serving as a condenser to change the steam back into water.

STEAM DOME. A steam dome is the dome-shaped projection on the top of steam boiler which acts as a reservoir in which the steam is comparatively dry; hence the steam for driving an engine is obtained from the dome. The throttle valve of a locomotive is in the dome and the steam flows forward to the cylinders through a pipe inside of the boiler.

STEAM DROP-HAMMERS. The steam drop-hammer for producing drop-forgings is commonly used in preference to the board drop-hammer for heavy drop-forging operations, especially when considerable " breaking down " or drawing is required. The capacity of steam drop-hammers, such as are used for the average drop-forging work, varies from 2000 to 5000 pounds, and, for very heavy forging operations, much larger sizes are used. A steam drop-hammer is constructed along the same general lines as a steam hammer, although there are certain variations in the design which adapt the hammer particularly to drop-forging work. The reciprocating movement of the ram is controlled by a piston valve and the hammer is

double-acting, steam being admitted above and below the piston the same as with an ordinary steam hammer. See also Drop-hammers.

STEAM ENGINE. A steam engine is a machine by means of which *heat* is transformed into *work*. When in action, a certain amount of steam (from one-fourth to one-third of the total cylinder volume in simple engines) is admitted to one end of the cylinder, while the other is open to the atmosphere. The steam forces the piston forward a certain distance by its direct action at the boiler pressure. After the supply is shut off, the forward movement of the piston is continued to the end of the stroke by the expansion of the steam. Steam is now admitted to the other end of the cylinder, and the operation repeated on the backward or return stroke. A valve operated automatically by a crank or eccentric attached to the main shaft, opens and closes the supply and exhaust ports at the proper time to control the flow of steam to and from the cylinder.

Classification. — There are various ways of classifying reciprocating steam engines according to their construction, the most common, perhaps, being according to speed. If this classification is employed, they may be grouped under three general headings: High-speed, from 300 to 400 revolutions per minute; moderate-speed, from 100 to 200 revolutions; and slow-speed, from 60 to 90 revolutions per minute, all depending upon the length of stroke. This classification is again subdivided according to the valve mechanism, and whether horizontal or vertical, simple or compound, etc.

Losses. — The principal losses in steam engines are due to friction, cylinder condensation, leakage, incomplete steam expansion, "wire drawing," and excessive clearance volume. The friction losses in the best types amount to only about 5 per cent of the total power produced, the percentage of frictional loss decreasing as the horsepower output increases.

Engine Rotation. — The eccentric of a steam engine is set in a certain relation to the crank, the general position depending upon the direction in which the engine is to run. The terms "running over" and "running under" are ordinarily used to indicate the direction in which an engine rotates. When the crank rises at the beginning of the forward stroke and the top of the flywheel turns away from the cylinder, the engine is said to be running over. Inversely, when the crank falls at the beginning of the forward stroke and the top of the flywheel turns toward the cylinder, the engine is running under. Stationary engines ordinarily are designed to run over, whereas locomotives must, of necessity, run under when moving forward. Assume that the engine is to run over; then, if the valve motion is direct, the eccentric rod being connected with the valve-stem so that the movement of the valve-stem is not reversed but in the same direction as the eccentric rod, the eccentric should be located on the shaft so that a

line passing through the centers of the crankshaft and eccentric will be a little over 90 degrees ahead of the center-line of the crankpin. The eccentric will then *lead* the crankpin when the engine is running; consequently, the position of the eccentric indicates the direction in which the engine will rotate. On the other hand, if the eccentric rod is connected to the valve-stem by a rocker arm, which gives the valve-stem a reverse movement (the motion being indirect), the eccentric should be so set that its center-line is a little less than 90 degrees back of the crankpin, the eccentric following the crankpin when the engine is in motion.

Multiple Expansion Engines. — Condensation losses in steam cylinders are due principally to the change in temperature of the interior surfaces caused by the variation in temperature of the steam at initial and exhaust pressures. If the temperature range be divided between two cylinders which are operated in series, the steam condensed in the first or high-pressure cylinder will be re-evaporated and passed into the low-pressure cylinder as steam, where it will again be condensed and re-evaporated as it passes into the exhaust pipe. Theoretically, this should reduce the condensation loss by one-half, and, if three cylinders are used, the loss should be only one-third of that in a simple engine. In actual practice, the saving is not as great as this, but with the proper relation between the cylinders, these results are approximated. Another advantage gained by compounding is the possibility to expand the steam to a greater extent than can be done in a single-cylinder engine, thus utilizing, as useful work, a greater proportion of the heat contained in the steam. This also makes it possible to employ higher initial pressures, in which there is a still further saving, because of the comparatively small amount of fuel required to raise the pressure from that of the common practice of 80 or 90 pounds for simple engines, to from 120 to 140 pounds in the case of compound engines. With triple expansion, initial pressures of 180 pounds or more may be used to advantage. The gain from compounding may amount to about 15 per cent over simple condensing engines, taking steam at the same initial pressure. When compound condensing engines are compared with simple non-condensing engines, the gain in economy may vary from 30 to 40 per cent.

STEAM ENGINE DEVELOPMENT. The steam engine was the result of an evolutionary development which was due to the work of several inventors. Although the most notable improvements were made by James Watt, considerable pioneer work had been done previously. In 1690 Denis Papin originated the first cylinder and piston type of steam engine, but the scheme was impracticable owing to the fact that both boiler and cylinder were combined in one vessel. Thomas Newcomen, in 1705, made a practical form of piston engine, although it was very crude and inefficient

and simply provided a reciprocating motion. About 1711 Newcomen's engine was introduced for mine pumping, and by 1725 it was in common use in collieries and continued in use for about three-quarters of a century. This engine was of the atmospheric type, depending for its action upon condensation of steam and the atmospheric pressure.

In 1763, James Watt, an instrument maker in Glasgow, while repairing a model of Newcomen's engine, perceived the waste of steam resulting from alternate chilling and heating of the cylinder. The result was the origin of the condensing apparatus, involving the use of a separate condenser, cooling water, and an air pump for maintaining a partial vacuum. Although this was a notable improvement, the engine was still suitable only for pumping, as it was a single-acting type with steam admitted during the entire stroke. Motion was transmitted from the piston to the pump rod through an oscillating " walking beam," but there was no rotary motion. In a second patent, issued in 1781, the sun and planet wheels and other methods of securing a continuous rotary motion are described. Watt had invented the crank and connecting-rod for this purpose, but meanwhile it had been patented by Pickard; hence, the sun and planet motion was used by Watt until the patent on the crank expired. In 1782, Watt patented two additional improvements of great importance. One was the double-action principle, whereby pressure is applied alternately to each side of the piston, and the other was in using steam expansively by stopping its admission when the piston had made only part of its stroke. Henry Maudslay made further improvements in the steam engine by eliminating the cumbersome wooden walking beam of the Newcomen and Watt engines, and connecting the cross-head and crank direct.

STEAM ENGINE HORSEPOWER RATING. The capacity or power of a steam engine is rated in horsepower, one horsepower (H.P.) being the equivalent of 33,000 foot-pounds of work done per minute. The horsepower of a given engine may be computed by the following formula in which P = mean effective pressure per square inch; L = length of stroke, in feet; A = area of piston, in square inches; N = number of strokes per minute = number of revolutions $\times$ 2.

$$\text{H.P.} = \frac{PLAN}{33{,}000}.$$

The derivation of this formula is explained, as follows: The area of the piston, in square inches, multiplied by the mean effective pressure, in pounds per square inch, gives the total force acting on the piston, in pounds. The length of stroke, in feet, times the number of strokes per minute gives the distance the piston moves through in feet per minute. The pressure in

pounds multiplied by the distance moved through in feet gives the foot-pounds of work done. Hence, $P \times L \times A \times N$ gives the foot-pounds of work done per minute by a steam engine. If one horsepower is represented by 33,000 foot-pounds per minute, the power or rating of the engine will be obtained by dividing the total foot-pounds of work done per minute by 33,000.

STEAM FLOW. See Darcy's Formula; also Napier Formula.

STEAM FLOW METER. See Flow Meter.

STEAM HAMMER. Steam hammers are used very extensively for forging operations on both small and large work, hammers of this kind being made in a large range of sizes. While "power hammers" are used in preference to steam hammers on certain classes of work, especially wherever comparatively light rapid blows are required, the steam hammer is the type that is best adapted to general forging operations on the heavier classes of work. The ram of a steam hammer is moved upward by steam which is admitted below the piston, and downward both by steam and the weight of the piston, ram, and die. The force of the blows may be varied by adjusting this throttle so as to admit a greater or less amount of steam to the cylinder. On small steam hammers, this throttle valve is sometimes connected to a foot lever or treadle, so that one man can operate the hammer without an attendant. While most steam hammers are constructed to run automatically, only the smaller sizes, varying from about 250 to 600 pounds capacity, can be operated to advantage with a foot lever connecting with the throttle valve. When forging comparatively small work, one man can hold the part being forged and operate a foot lever after the controlling lever has been set to give blows of the required force, but, for heavier work, it is necessary to vary the blows more than is possible with the automatic operation, and the turning of a heavy piece upon the anvil requires the entire attention of one man and makes the foot-lever control impracticable.

STEAM HAMMER INVENTION. The steam hammer was invented in 1839 by James Nasmyth, an English inventor and tool builder. Before he had had time to build one, the immediate need for it passed and he did nothing further with it. His sketch, however, was shown from time to time to various people, among them M. Schneider of Creuzot, France. In 1842, three years after the sketch was made, Schneider showed Nasmyth, when in France, some wonderful forgings, made, he said, on his steam hammer. Nasmyth was taken out to the forge shop and was surprised to see the steam hammer which he had invented. Fortunately he could still cover the machine by patent, and two months later one was obtained.

The history and the influence of the steam hammer are well known. This tool enormously increased the facilities in manufacturing heavy machinery.

STEAM HAMMER RATING. The capacity of a steam hammer or its rating is the weight of the ram and its attached parts, such as the piston and the rod. The steam pressure behind the piston is not considered, as far as the rating is concerned. For example, a 1000-pound hammer has reciprocating parts of that weight. The steam pressures for operating hammers usually vary from 75 to 100 pounds per square inch. The capacity of a steam hammer or the proper size to use for working iron and steel of a given cross-sectional area can be determined approximately by the following rule: Multiply the area of the largest cross-section to be worked by 80, if of steel, or 60, if of iron, and the product will be the required rating of the hammer in pounds. For example, the capacity of a hammer for working steel billets 5 inches square would be determined as follows: $5 \times 5 = 25$; and $25 \times 80 = 2000$, which is the rating of the hammer in pounds. A hammer rated according to this rule is an economical size to use, and it can be employed for heavier work.

STEAMING CAPACITY. This is the weight of dry steam that a steam boiler will evaporate in a given time without regard to the weight of the fuel required.

STEAM METAL. Alloys suitable for steam valves and other purposes where the metal is exposed to the action of the steam are often known as "steam metals." Alloys of copper and zinc are unsuitable for this purpose, because their strength is materially reduced at high temperatures and the metal deteriorates by continued heating and cooling. Alloys of copper with from 10 to 12 per cent of tin are, therefore, used for this purpose. A good composition consists of 88 per cent of copper, 10 per cent of tin, and 2 per cent of zinc. This alloy has a tensile strength of about 33,000 pounds per square inch, when cold, and over 30,000 pounds per square inch, when heated to 400 degrees F.

STEAM PIPE VIBRATION. See Vibration Due to Steam Flow.

STEAM SEPARATORS. Steam separators are used in steam power plants in order to intercept the moisture in the steam and the water of condensation that flows along with it, before the steam reaches the engine cylinders or turbines, thus protecting them from damage by water. It is a well-known fact that steam engines and turbines operate more economically and at higher efficiency when supplied with dry steam than when supplied with moisture-laden steam. For this reason, a steam separator will effect a saving in fuel and also a considerable saving in oil and engine repairs.

STEAM TABLES. Steam tables may be found in many engineering handbooks, and in the catalogues of various kinds of steam apparatus. They give useful data relating to steam at different pressures, and include such factors as: 1. pressure; 2. temperature; 3. heat in water above 32 degrees F.; 4. internal latent heat; 5. external latent heat; 6. latent heat of evaporation; 7. total heat of evaporation; 8. weight of a cubic foot of steam, in pounds; 9. volume of a pound of steam, in cubic feet.

STEAM TURBINE. See Turbine, Steam.

STEAM TURBINE BLADE ALLOYS. See Cupro-nickel; also under Stainless Steel.

STEARTITE. Same as Talc.

STEEL ABRASIVES. Steel abrasives are small globules or particles of steel made by a method that gives them unusual hardness and toughness. These abrasives are used in a process similar to that of sand-blasting, the difference being that the abrasive action is from the steel particles instead of using sand.

Steel abrasives are first made into round globules or shot by a blowing process. Each globule, after being blown to shape, is quenched, the rapid chilling giving it a very close dense structure. A subsequent heat-treatment reduces the chilling strains set up by the quenching, so that the shot or abrasive will resist impact and wear in a satisfactory manner.

Chilled shot, being round, is used when work can be cleaned by shock. The round globules act like numerous ball-peen hammers. The peening action gives satisfactory results in cleaning rough work, the surface of which is not intended for subsequent enamelling, galvanizing or plating. For work which is to be subsequently treated by any one of the processes just mentioned, what is known as angular steel grit is used. Angular grit is chilled shot broken down to produce sharp angular corners. The angular grit retains the original physical properties of hardness and toughness, but in blasting operations it has the advantage of producing both impact and actual cutting action. It cuts like numerous sharp tools, actually removing minute chips from the surface being blasted and producing a matte finished appearance. The coarseness or fineness of the surface can be controlled by the size of the angular grit used. The fact that steel abrasive actually cuts, makes possible much more rapid production than with sand.

The crushing of shot to make angular grit is an expensive operation due to the rapid wear of the crushing tools. It is also impossible to control the sizes in the crushing except in a very limited way, and a certain loss, therefore, results from pulverizing part of the crushed material into small unsaleable sizes. This loss, together with the actual cost of the crushing opera-

tion, makes the cost of angular grit somewhat higher than of globular shot. This, however, is offset by its capacity for faster blasting production and cleaner work.

Steel abrasive, either in the form of shot or angular grit, can be used over and over again hundreds of times. It is superior to sand in that it does not break down like sand does, and one ton of steel abrasive will do the work of a carload of the very best sand-blast sand. In general, the relative ultimate cost based on work produced by steel abrasive as compared with sand-blast sand, is only about from one-quarter to one-half of the latter.

The nozzles of the blast also last from two to four times longer with steel abrasives than with sand. The slower wear of the orifice also effects a big saving in compressed air. The dust due to ordinary sand-blasting is practically absent, as there is no dust from the metal abrasives themselves. Much storage space is saved as compared with that needed for sand, and the handling charge is very much reduced.

STEEL BELTS. Endless steel belts are made of thin strips of sheet steel and are applied to pulleys like leather belts. See Belt Materials.

STEEL CASTINGS. Steel castings may be defined as unforged and unrolled castings made of Bessemer, open-hearth, crucible or electric-furnace steel. Great improvements have taken place in the production of steel castings, the chemical composition to give certain desirable properties having been determined, and the methods to be used in the steel foundry for producing the best results having been improved. The tensile strength and elastic limit of steel castings have been increased about 50 per cent over that of twenty-five years ago, and the resistance to impact has been increased to a still greater extent. As steel castings are stronger than wrought, cast, or malleable iron, and as they are extremely tough, they are especially useful for machine parts that must carry heavy loads and withstand thrusts and shocks incident to hard service. Steel castings may now be obtained which have a tensile strength of 60,000 pounds and an elastic limit of 30,000 pounds. In the case of high-carbon steel castings, these figures are exceeded by from 25 to 50 per cent. See also Stainless Steel Castings.

STEEL COLORING. A method of bluing iron and steel, in order to obtain pleasing color effects, known as the *niter process*, consists in melting niter or nitrate of potash, also called "saltpeter," in an iron pot at a temperature of about 600 degrees F. The parts to be blued are cleaned and polished and immersed in the molten nitrate of potash until a uniform color of the desired shade has been obtained. This requires only a few seconds. The articles are then removed, allowed to cool, and the adhering niter

washed off in water. If there is no danger of warping, the parts may be immersed in the water immediately after having been removed from the nitrate-of-potash bath. The articles are then dried in sawdust, and linseed oil is applied to prevent rusting. To secure uniform colors, a pyrometer should be used to gage the temperature of the nitrate-of-potash bath, because high heats will produce darker colors, whereas lower heats will give lighter shades.

Brown Finish. — The following is the standard formula used by the United States Government for browning gun barrels and similar steel articles: Alcohol, 1½ ounce; tincture of iron, 1½ ounce; corrosive sublimate, 1½ ounce; sweet spirits of niter, 1½ ounce; blue vitriol, 1 ounce; nitric acid, ¾ ounce; and warm water, 1 quart. Dissolve the above ingredients in the water and keep in a glass bottle. The gun barrel to be treated is cleaned with potash of soda to remove the grease, and all stains are then removed with fine emery cloth, so that an even bright surface is produced. The bore and vent of the barrel are closed by plugs of wood. The solution is then applied to the surface of the steel with a sponge and allowed to dry in the air for 24 hours, after which the loose rust is rubbed off with a steel scratch brush. Another coating of the solution is now applied, and allowed to dry in the same manner, after which the scale is again rubbed off with a scratch brush. Finally the barrel is washed in boiling water, dried rapidly, and wiped with boiled linseed oil or given a coat of shellac. See also Gun-metal Finish on Steel.

STEEL, COPPERIZED. Tests made by a committee of the American Society for Testing Materials with the coöperation of the United States Bureau of Standards, together with other data available, prove that by alloying from 0.15 to 0.25 per cent copper with normal open-hearth or Bessemer steel, the rate of corrosion of steel is very much reduced, where the products are exposed to alternate attacks of air and moisture. Two heats of basic open-hearth steel were copperized in varying amounts from about 0.01 per cent up to 0.25 per cent. Sheets from different ingots were made and exposed to the weather for various lengths of time. The tests proved that very low amounts of copper in steel tend to lower the corrosion rate. Copper, to the extent of 0.12 per cent, is said to be sufficient to neutralize the influence of sulphur amounting to 0.055 per cent. Copper amounting to 0.15 per cent is sufficient to protect steels even if the sulphur content is much higher than normal.

STEEL FOUNDRIES CLASSIFIED. The steel foundry industry may be divided into three general branches, in an industrial or commercial, rather than a technical sense. These are as follows:

1. Open-hearth foundries (ordinarily employing acid-lined furnaces),

producing miscellaneous steel castings of sections varying from medium to heavy, and having over-all dimensions that cover a very wide range.

2. Open-hearth foundries (generally using basic-lined furnaces), making castings consisting mainly of repetition work as specialties for railroad use. The castings are generally characterized by moderate sections. Few foundries making the product mentioned, produce specialties having large over-all dimensions.

3. Electric foundries (almost invariably employing acid-lined furnaces), and converter foundries (always using acid-lined vessels), specializing in castings that have thin sections, and small or medium over-all dimensions.

STEEL, HOT-PRESSED. See Hot-pressed Steel Parts.

STEELS. The word "steel" is applied to many mixtures which differ greatly from each other in their chemical as well as physical qualities.

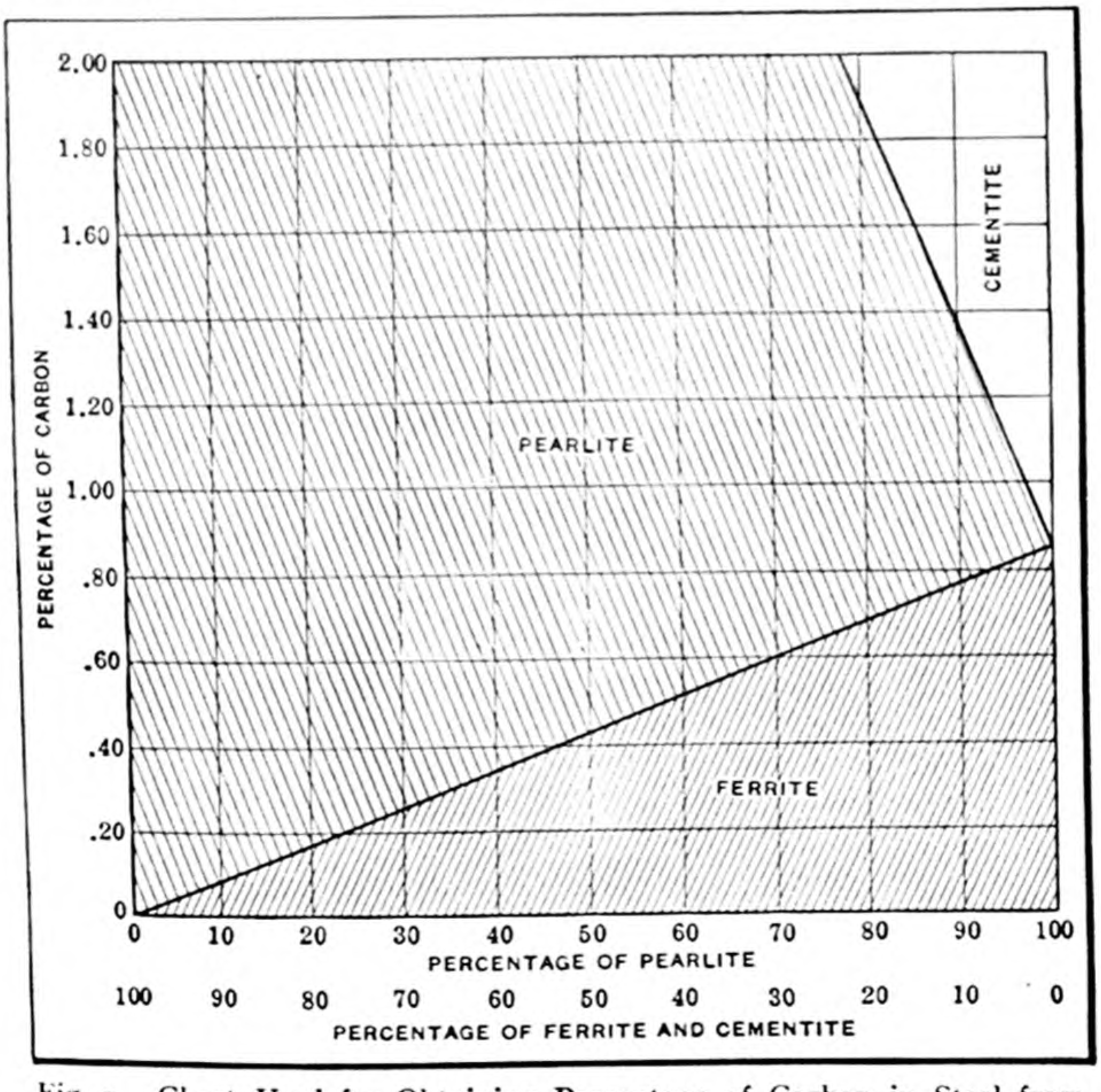


Fig. 1. Chart Used for Obtaining Percentage of Carbon in Steel from Appearance of Micrograph

The ingredient that exerts the most influence on steel is carbon. High-grade razor steel contains about 1.25 per cent of carbon; spring steel, 1 per cent; steel rails, from 0.50 to 0.75 per cent; and soft steel boiler plate may have

as little as 0.062 per cent of carbon. Steel which is very low in carbon can easily be welded, but it cannot be hardened; when the carbon is above 0.33 per cent, welding is more difficult and can be done only by the use of borax or some other flux, or by the electric or thermit processes. Steel with carbon above 0.75 per cent can readily be hardened. In tool steel, other ingredients than carbon are sometimes used to influence its hardness, such as nickel, manganese, chromium, tungsten, etc., the last named playing an important part in so-called "high-speed steels," that is, tool steels

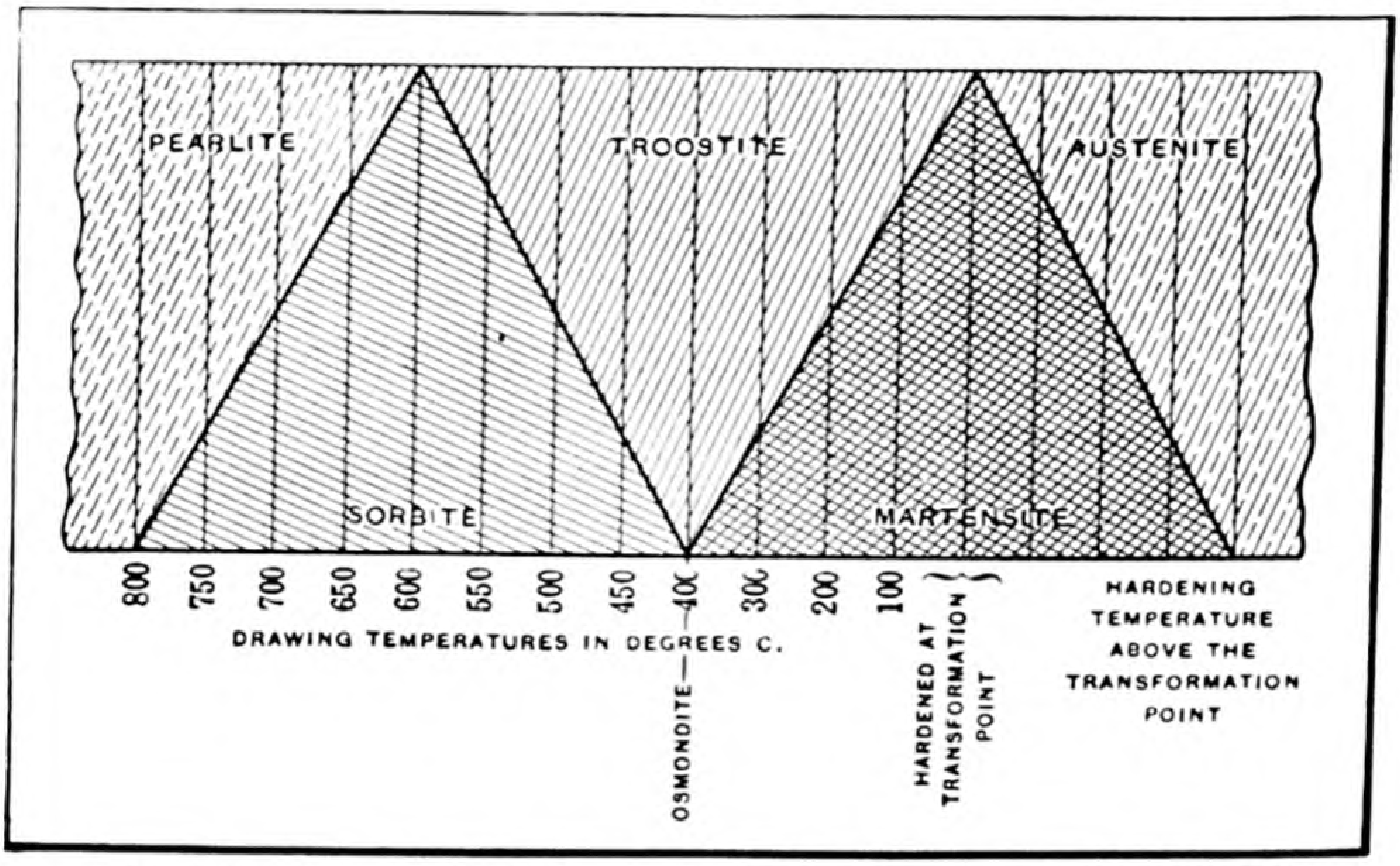


Fig. 2. Constituents of Steel Seen with Microscope and Their Relation to Hardening and Drawing Temperatures

that will cut metal at a high speed without losing their temper or hardness. Pig iron and cast iron contain about 4 per cent of carbon, and wrought iron only a trace of it, while steel is between these two extremes; hence, in the manufacture of steel, it is important to obtain the right proportion of carbon. One method is to burn the carbon out of pig iron, as in the Bessemer and open-hearth processes, and the other method is to add carbon to wrought iron, as in the crucible process.

First Steel Made in the United States. — The first steel produced in the United States, according to the Geological Survey, Department of the Interior, was probably made in Connecticut in 1728, by Samuel Higley and Joseph Dewey. Crucible steel was first successfully produced in the United States in 1832 at the works of William and John H. Garrard, at Cincinnati, Ohio. Bessemer steel was first made in this country in September, 1864, by William F. Durfee, at an experimental plant at Wyandotte, Mich., and open-hearth steel by the New Jersey Steel & Iron Co. at Trenton, N. J., in the same year as the first Bessemer steel.

Steel Under the Microscope. — In annealed steel, the constituents that

are visible under the microscope are ferrite, pearlite, and cementite. Ferrite is pure iron, and, when carbon is added to it, each atom of carbon absorbs three atoms of iron, or combines with it. This carbide of iron is called *cementite.* Pearlite is an intimate mixture of cementite and ferrite, in the definite proportions of 32 parts of ferrite to 5 parts of cementite; thus it contains 0.90 per cent of carbon. Therefore, when the carbon content of steel reaches 0.90 per cent, a microscopical examination will reveal only pearlite. Below this percentage, the surface will show pearlite and ferrite, with the pearlite constantly decreasing until the carbon content becomes nil, and then the surface will be entirely ferritic. Above a content of 0.90 per cent of carbon, the polished surface of the steel will show both pearlite and cementite, until a carbon content of 6.6 per cent is reached when only cementite will be seen. By using the chart shown in Fig. 1, the carbon content of steel can be calculated from the view obtained with the microscope. As an example, if 70 per cent of the area seen in the microscope shows ferrite and 30 per cent shows pearlite, the vertical line indicating 30 per cent of pearlite is followed upward until it intersects the diagonal line that separates the ferrite from the pearlite. The horizontal line through this point of intersection is then followed to the left to find the percentage of carbon in the steel. In this example, it will be 0.270 per cent of carbon.

Etching Reagents. — In preparing specimens for microscopical examination various methods of etching are resorted to for developing them. This treatment cuts away certain constituents and makes others stand out in relief. These raised portions resemble hills and plateaus, in miniature, which show white from the reflected light in the microscope; while the portions cut away are valleys that receive no light and are thus black. In some cases, constituents are colored by various etching materials and are thus distinguished by their color. The three most commonly used etching materials are picric acid, nitric acid, and tincture of iodine.

Heat Treated Steel. — In heat-treated steels, the constituents ferrite, pearlite, and cementite are replaced by others, and it is in the heat-treated steels that the microscope has been of the greatest practical benefit. Many different constituents are formed as a result of the various degrees of temperature to which steels are submitted for annealing, hardening, tempering, and carburizing, and other etching materials have been found to develop them better. The way in which the metal is affected by each change in temperature is thus revealed. To give the steel the correct temper, it is first necessary to obtain the greatest hardness that the metal is inherently capable of attaining, without a coarsening of the grain. As this leaves the steel quite brittle, it is afterward drawn enough to bring back the desired amount of toughness and ductility. When steel is being heated, it reaches a point where it loses its magnetism. If the heat is measured

with a pyrometer, the pointer that indicates the temperature will halt in its upward travel when this point is reached. This is due to a transformation that is taking place in the steel. In other words, a new grain structure is being born and the temperature of the metal ceases to rise until the transformation is completed and each crystal has absorbed the required amount of heat to effect this change. In most steels this change of structure occurs below 810 degrees C. (1490 degrees F.), and, if the steel is quickly reduced to atmospheric temperature, this new grain structure will be preserved. It is the finest grain structure that can be produced in the metal and the steel is as hard as it can be made without coarsening the grain. The constituent in steel which develops when it is heated to the temperature mentioned is known as *martensite*.

Austenite. — If steel is heated above the transformation point and suddenly quenched, as in ice water, a constituent called *austenite* is developed. The grain is also coarsened, and the higher the temperature, the coarser will be the grain. The line of demarcation between the crystals becomes more and more pronounced as the temperature rises, and this indicates a weakening of the metal, as the substance of which these lines are composed is very hard and brittle. In fact, when the temperature is increased very much beyond the transformation point, the internal strains cause microscopic cracks to appear, and these develop into distinct cleavages between the crystals. Thus, to quench steels from above the transformation point has a weakening effect, which is due to the separation of the crystals.

Martensite. — When the hardening temperature is too high, austenite and martensite are both developed. When the temperature is the correct one, however, only the martensite is seen in the polished surface of the steel. The martensite formation resembles a mass of needles that intersect one another in the direction of the sides of an equilateral triangle. All steels that contain more than 0.16 per cent of carbon and have been hardened will develop the martensitic structure. It is easily retained by any of the hardening and quenching methods; and is the hardest of all the constituents formed in the steel and very brittle. The more martensite that is present, the greater will be the degree of hardness of the metal.

Ferrite and Troostite. — In the low-carbon steels, free ferrite develops with the martensite, and the lower the carbon content, the more ferrite will be present. In large steel pieces, the center is not affected by the heat-treatment as much as the outer portions, and another constituent, known as *troostite*, is usually intermingled with the martensite. The martensitic structure of hardened steel is changed into troostite by drawing out a part of the hardness; this is done by reheating it to temperatures below 400 degrees C. (750 degrees F.). As the drawing temperature rises up to 400 degrees C. (750 degrees F.) the martensite gradually disappears

and troostite takes its place. Troostite is almost amorphous and generally appears in irregular areas that are dark colored. It is sometimes slightly granular. The white places that appear are needles of martensite, which remained in the steel because the drawing temperature was not high enough to convert it all into troostite. Thus it is called a *troosto-martensitic steel.* The temperature at which the metal was drawn can be judged from the amount of each constituent that is present. When a drawing temperature of about 400 degrees C. (750 degrees F.) is reached, the martensite disappears and the steel is then named *osmondite*, it is the boundary between troostite and sorbite, which is developed by higher drawing temperatures.

Sorbite. — When the drawing temperature is approximately between 400 degrees and 800 degrees C. (750 and 1470 degrees F.), the constituent called *sorbite* is developed, which reaches its maximum at 600 degrees C. (1110 degrees F.), and the polished surface will then be entirely sorbitic. Hardened steels that have been reheated for tempering to between 400 degrees and 600 degrees C. (750 and 1110 degrees F.) will show both troostite and sorbite, and these are called *troosto-sorbitic steels.* The amount of each constituent that is present will show the temperature at which the steel was drawn. With the drawing temperature from 600 degrees to 800 degrees C. (1110 to 1470 degrees F.), both sorbite and pearlite can be seen, while above 800 degrees C. only the pearlite, ferrite, and cementite, of the thoroughly annealed steels, are visible. The chart shown in Fig. 2 illustrates how the various constituents overlap each other and how the use of the microscope enables one to judge the drawing temperature from the amount of each constituent that is present. Sorbite is softer and tougher than troostite, and troostite is softer and tougher than martensite. Pearlite is softer than any of the others, while austenite is more brittle. Thus, as these various constituents intermingle with one another, they impart to the steel the hardness, toughness, ductility, strength, or other properties in the exact proportion to the amount of each constituent that is present.

STEELS, CLASSES. See kind of steel or process: Air-hardening Steel; Carbon Steel; Chromium-vanadium Steel; Cobaltcrom Steel; Crucible Steel; Electric Steel; High-speed Steel; Manganese Steel; Molybdenum Steel; Natural Alloy Steel; Nickel-chromium Steel; Nickel Steel; Spring Steels; Stainless Steel; Titanium Steel; Tungsten Steel; Tool Steel; Vanadium Steel; Bessemer Process; Open-hearth Process; Gear Steels; Drop-forging Steel.

STEELS, NORMAL AND ABNORMAL. The terms "normal" and "abnormal" are generally used to differentiate between a steel that will harden 100 per cent hard and a steel that will have soft spots after hardening in the ordinary way, without the use of cyanide or salt baths. It has been

demonstrated that it is often possible to harden an abnormal steel 100 per cent hard by the use of cyanide or salt baths.

STEELS, PRODUCTION. All commercial iron or steel contains iron as the chief constituent, but the percentages of carbon and other elements and the methods by which iron or steel are produced, as well as the processes to which they may be subjected, so change the characteristic properties that there are many distinct forms of iron and steel, some of which have properties so different as to appear like different metals. The main classes are pig iron, wrought iron, Bessemer steel, open-hearth steel, crucible steel, alloy steel, cast iron, and steel castings. Pig iron is the product into which the iron ore is first converted in a blast furnace. From pig iron, all commercial irons and steels are made. Wrought iron is produced by what is known as the "puddling" process. It contains a lower percentage of carbon than other forms of iron and steel, and is fibrous, ductile, and malleable. When heated, it can be formed and shaped readily by forging, and can easily be welded. Bessemer steel is made from pig iron in a Bessemer converter; hence its name. Open-hearth steel is produced from pig iron in a so-called "regenerative" furnace, the hearth of which is exposed to the action of the flame. Steel made by both the Bessemer process and the open-hearth process is used for rails, and also for structural iron shapes. It is also often known as "mild steel" or "machine steel." Crucible steel is made from high-grade wrought iron, by adding carbon to it, by melting the wrought iron in crucibles containing the proper amount of powdered charcoal. Crucible steel generally contains a larger percentage of carbon than any of the other steels, and is frequently termed "tool steel," because it is mainly used for cutting tools. Tool steels however are also made in the electric furnace and by the open-hearth process. Alloy steels may be made by any of the processes mentioned, by adding other metals, such as chromium, nickel, tungsten, etc. Cast iron is generally produced from pig iron in what is known as a "cupola" furnace. It contains a larger proportion of carbon than any of the other forms of iron or steel, and is easily cast in molds, but is neither ductile nor malleable. Steel castings are made from steel, generally melted in an open-hearth furnace, electric furnace, or a small Bessemer converter; crucible steel castings are also made.

At one time, there was quite a distinct line of demarcation between wrought iron and steel, but now these are distinguished mainly by their physical characteristics, wrought iron having a fibrous structure, while steel has more of a grain or crystalline structure.

Bessemer and Open-hearth Steels. — Most of the steel used at the present time for structural purposes, is made by the open-hearth process. The

tonnages of the Bessemer and open-hearth processes were about equal in the United States in 1907, but in 1912 the open-hearth furnace produced approximately twice as much steel as the Bessemer converter and since then the open-hearth process has been gaining steadily. Better grades of structural steel are made in the open-hearth furnace, and the process produces a more uniform and reliable steel than the Bessemer, as the operations are under better control. For additional information on steel-making refer to the different processes mentioned.

Steel-making by Direct Process. — The larger portion of the steel-making pig iron is transported in molten condition from the blast furnace to the steel mill and is never marketed in the form of pig iron at all. Similarly, during the initial stages of rolling steel products, the ingots, blooms, and slabs are merely intermediate stages in the production of steel and not ordinarily commercial products. Thus, before the ingot has lost the heat acquired in producing the steel itself, it has been rolled into a bloom, a slab, or a billet and is ready to be rolled into some finished rolled product, such as rails, plates, or structural shapes. This saving of heat and the use of automatic machinery in handling these heavy rolled products keep down the fuel and labor costs; therefore, the prices of the heavy products are largely controlled by the cost of the crude steel. But in the case of light-rolled products, such as wire rods and sheets, more rolling is required, with a corresponding loss of heat and greater use of hand labor; therefore, the prices of light-rolled products are largely influenced by the fuel and labor costs.

STEELS, STRENGTH. The strength of iron and steel varies considerably according to the quality of the material and the treatment to which it has been subjected. Both mechanical working and heat-treatment have a decided effect on the strength of steel; hence the strength figures which follow are given only as a general guide.

Bessemer and open-hearth mild steels have a tensile strength of about 60,000 pounds per square inch, and a compressive strength of practically the same value, with a modulus of elasticity of 29,000,000. This class of steel is that used as structural steel for beams, etc., or as boiler steel for plates. Structural steel for rivets is assumed to have a tensile and compressive strength of about 55,000 pounds per square inch, and boiler steel for rivets, a tensile and compressive strength of about 50,000 pounds per square inch. Spring steel of the best quality may have a tensile and compressive strength of up to 125,000 pounds per square inch. Alloy steels are still stronger, according to their composition and heat-treatment. The tensile strength of a low-carbon $3\frac{1}{2}$ per cent heat-treated nickel steel may vary from 75,000 to 150,000 pounds per square inch, depending upon the

drawing temperature. Some nickel-chromium steels vary in tensile strength from 120,000 to 220,000 pounds per square inch owing to different heat-treatments, and alloy steels in general commonly have tensile strength variations ranging from 100,000 to 200,000 pounds per square inch.

Steel wire varies in strength according to its condition and quality. Annealed steel wire has a tensile strength of 80,000 pounds per square inch; unannealed steel wire, 120,000 pounds per square inch; crucible wire, 180,000 pounds per square inch; suspension-bridge wire, 200,000 pounds per square inch; plow-steel wire, 270,000 pounds per square inch; and piano wire, 300,000 pounds per square inch. High-class wire is made in fine sizes only, so that these high values for strength per square inch would not apply to a bar actually one inch square, but only when fine wire is drawn from the metal.

Effect of Mechanical Working. — The strength of a steel depends upon the manner of working it as well as upon its chemical composition. If steel is not thoroughly worked it will be soft, weak, and not very tough. A plate 2 inches thick is not as strong and tough, proportionately, as a plate $\frac{1}{4}$ inch thick, because the thinner plate is much more thoroughly worked. Excessive working, on the other hand, lessens the ductility. For instance, the strength of a steel may be about doubled by drawing it into wire, but the ductility will be reduced to a very small fraction of 1 per cent. When steel is " cold drawn " or " cold rolled," as the process is frequently although erroneously called, its tensile strength may be increased as much as from 20 to 40 per cent and its elastic limit from 60 to 100 per cent; but its elongation is reduced. By this process the steel is given a hard skin or shell, but the core is unchanged. If the steel contains a large proportion of carbon, the manner of cooling after working will also have a very important effect. Sudden cooling or " hardening " has an effect similar to that of cold working. Steel worked at a blue or black heat is injured more than if strained when cold. This property is known as *blue shortness*. Steel is also affected by such action as shearing or punching, so that it is preferable to drill holes in steel plates rather than to punch them. The crushing stress exerted upon the edge of the plate in shearing has been found to have greater effect upon the quality of the metal in the case of steel than in the case of wrought iron.

Effect of Temperature. — Varying temperatures have a decided effect upon the strength of iron and steel. Intense cold raises the limit of elasticity of both iron and steel, but does not affect their tensile strength. It reduces their resistance to impact, however. With a rising temperature from that of the normal temperature of 70 degrees F., there is first an increase in strength and then a rapid drop. Tests have been made to determine the strength of iron and steel at high temperatures. The results

show that as the temperature is increased, steel, wrought iron, and cast iron grow stronger up to a certain point. According to one test, the maximum strength of wrought iron is reached at 450 degrees F., and the corresponding temperature for steel is 525 degrees F. With further increase in temperature, both the ultimate and elastic strength decrease rapidly.

According to another test, structural steel has a strength of 132 per cent at 400 degrees F., 122 per cent at 570 degrees F., 86 per cent at 750 degrees F., and 28 per cent at 1100 degrees F. Cast steel has its highest value of strength of 125 per cent at 400 degrees F., which is reduced to 121 per cent at 570 degrees F., to 97 per cent at 750 degrees F., and to 57 per cent at 930 degrees F. These figures are, of course, subject to variation, but are given in order to indicate the probable weakening of various irons and steels with increasing temperatures.

STEEL WIRE GAGE. This gage is used in the United States for all bare wire of galvanized and annealed steel and iron, and also for all tinned and spring steel wire. It is also known as the United States Steel Wire Gage, Washburn & Moen Wire Gage, American Steel & Wire Co.'s Gage, Roebling Wire Gage, and National Wire Gage. Steel Wire Gage tables may be found in Engineering Handbooks.

STEEL WOOL. Steel wool is made by shaving thin layers of steel from high-manganese Bessemer wire. The wire is pulled, by special machinery built for the purpose, under cutting tools so arranged that they shave off chips much in the same way as a hand plane would shave off chips from a wooden pole. In later types of machines the wool is also produced by drawing the wire through circular cutting dies which shave off chips from the outside.

Steel wool consists of long, relatively strong, and resilient steel shavings, of polygonal cross-section, usually triangular, but always possessing three or more sharp edges. This characteristic renders it an excellent abrasive and a strong competitor of sandpaper and similar abrasives in the woodworking industries. The fact that its cutting characteristics vary with the size of the fiber, which is readily controlled in manufacture, has enabled it to find special markets such as the household, particularly for rapid cleaning of aluminum and other cooking utensils. The coarser grades are used to a large degree by painters for the preparation of surfaces to be painted.

Metals other than steel have been made into wool by the same processes as steel, and when so manufactured have the same general characteristics. Thus wool has been made from copper, lead, aluminum, bronze, brass, monel metal, and nickel. The wire from which steel wool is made may be produced by either the Bessemer, or the basic or acid open-hearth processes. It should contain from 0.10 to 0.20 per cent carbon; from 0.50 to 1.00 per

cent manganese; from 0.020 to 0.090 per cent sulphur; from 0.050 to 0.120 per cent phosphorus; and from 0.001 to 0.010 per cent silicon. When drawn on a standard tensile-strength testing machine, a sample of the steel should show an ultimate strength of not less than 120,000 pounds per square inch.

STEEPLE BLOWING ENGINE. This is a blowing engine of the vertical type, in which the steam and air cylinders are arranged in tandem, the steam cylinder being below the air cylinder. The name is derived from the unusual height of the engine.

STELLITE. Stellite, or Haynes stellite, is a composition of chromium, cobalt and tungsten. One of its outstanding properities is its ability to retain its hardness almost unimpaired up to a bright red heat. In addition to its " red hardness " it has the property of resuming its original hardness upon cooling, provided it has not been heated much above 1000 degrees Centigrade. These features combine to make stellite suited for the machining of other metals, even though at ordinary temperatures and up to 600 degrees Centigrade it is not quite so hard as the hardest of the plain carbon or high-speed alloy steels heat-treated in a manner to develop the best cutting qualities. On account of its red hardness and because it is durable under attrition, stellite has been found efficient for the high-speed cutting of cast iron, semi-steel, malleable iron, mild steel, steel castings, bronze, hard rubber and fibre. Tools may be made of solid stellite, or a small piece may be welded to the end of a steel shank. Stellite is only feebly attracted by a magnet and cannot be magnetized; this is an advantage in a cutting tool.

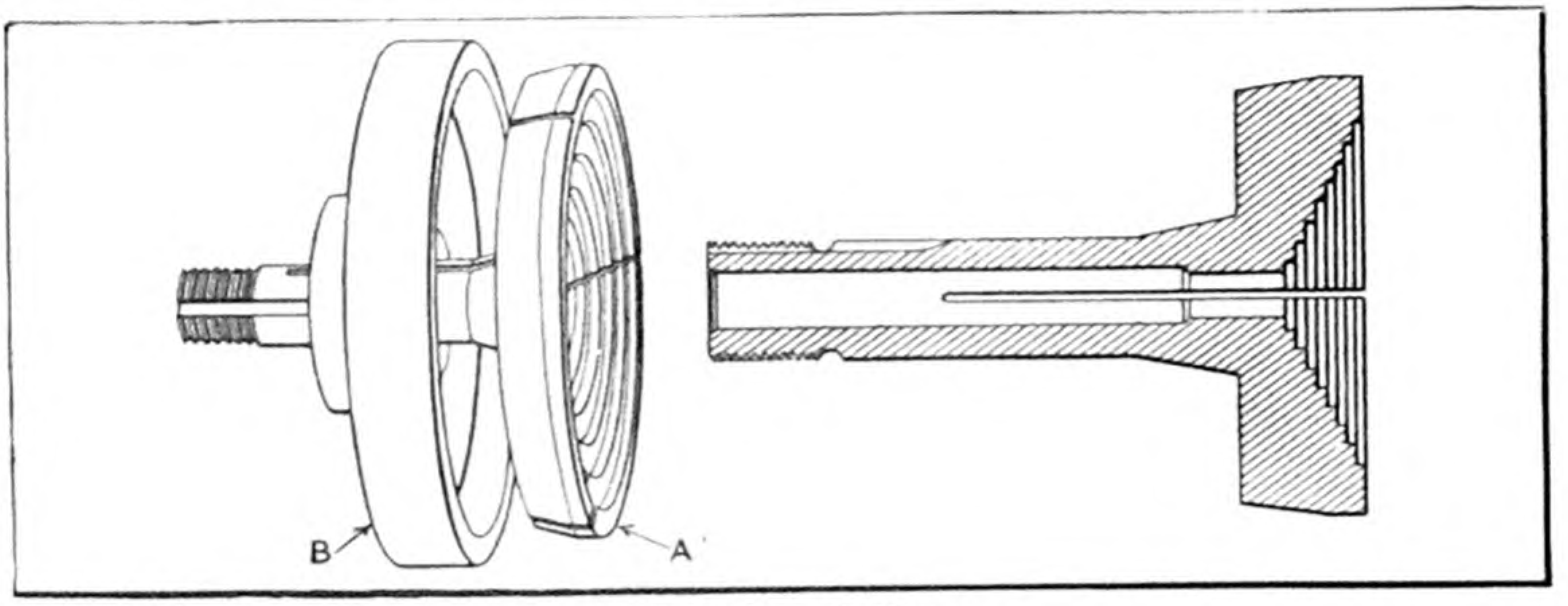
Stellite can be deposited upon steel and cast-iron surfaces by fusion welding, the process is known as " Stelliting." Stellite is entirely resistant to nitric acid under all conditions, also to the most important of the organic acids, and to a considerable number of corrosive solutions employed in the industries. It is also inert toward amalgamation with mercury. It has the untarnishable qualities of gold and platinum and takes a high silver-white polish.

Some of the uses to which stellite has been put are: metal-cutting tools for various machining operations; milling cutter blades; plug gages; lathe and grinder centers; centerless grinder workrests; scrapers for hot billets; dies for drawing, pressing, hot-forming and hot-shearing; knives; valves and valve seats; bushings; mirrors and reflectors; and dental instruments.

STEP BOLT. A step bolt is a bolt similar to a carriage bolt, except that the head is much flatter, although of spherical form.

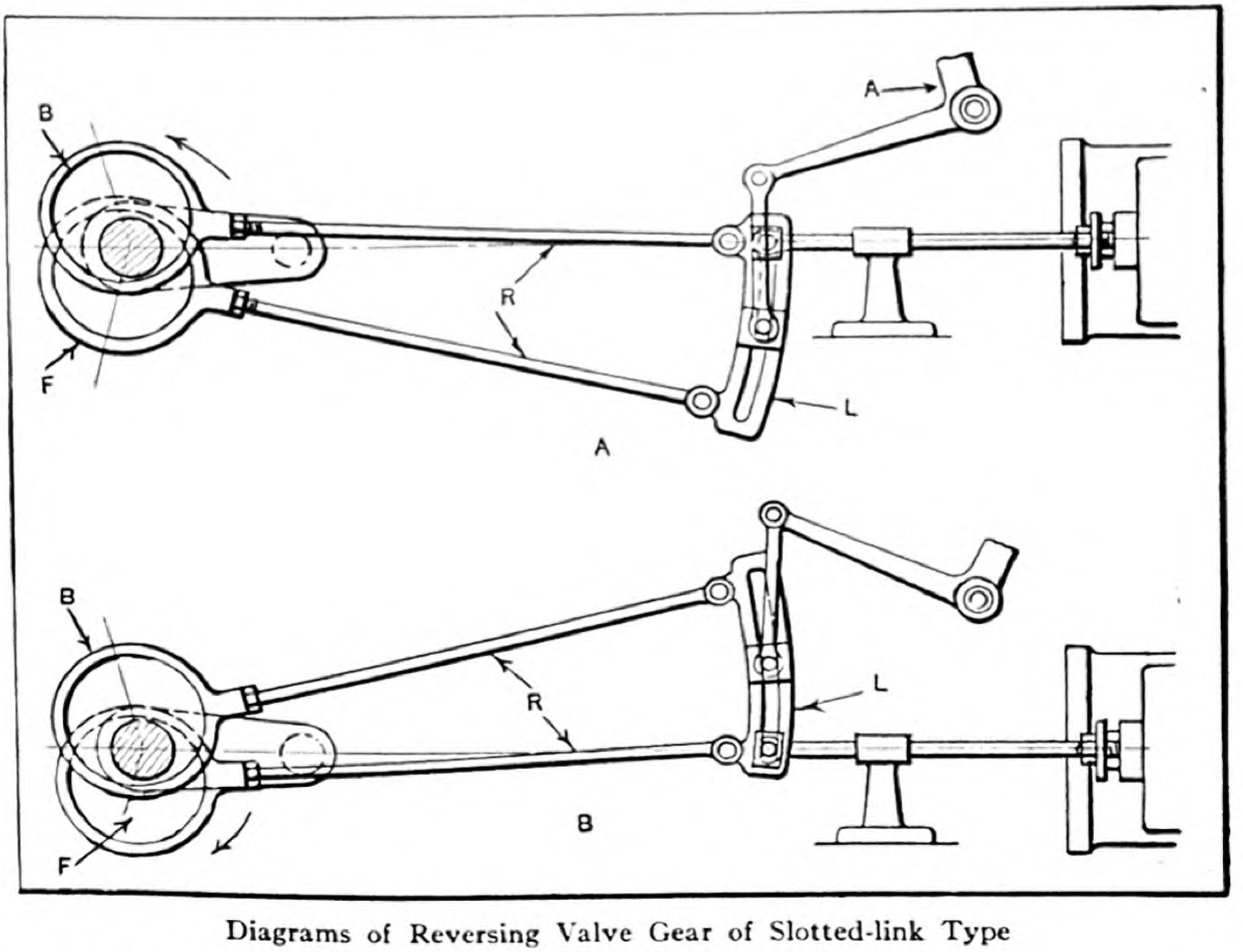
STEP-CHUCK. The step- or " wheel " chuck is a form having a series of annular recesses or steps of various diameters, for holding work which must be located very accurately with reference to its periphery. These

chucks are used for work of larger diameters than could be held in a collet chuck. The part *A* (see illustration), is the chuck proper, and the outer



Step-chuck and Closer

member *B* is known as the *closer*, because it serves to close in the chuck as the latter is drawn back by the drawback spindle of the lathe.



Diagrams of Reversing Valve Gear of Slotted-link Type

STEPHENSON LINK MOTION. The general arrangement of the Stephenson link motion for operating engine valves, is shown by the accom-

panying diagrams. The principal parts are the eccentrics *F* and *B*; the eccentric rods *R*; and the link *L*. Each eccentric is surrounded by an eccentric strap which is free to revolve so that, as the eccentrics rotate, they act the same as cranks and impart a reciprocating motion to the slide valve enclosed in the steam chest. Two eccentrics are necessary, if the engine must run either forward or backward. By means of the reversing lever *A*, the end of the forward motion eccentric rod can be placed opposite the valve rod connection and then the motion of the valve will be derived from the forward eccentric. Similarly, when the link *L* is shifted by means of the reversing lever and its connections, the backward motion eccentric actuates the valve, and the direction of movement is reversed. When the link is either all the way down or up as far as it will go, the valve is given the maximum travel, and, as the link is shifted toward the central or neutral position, the travel gradually decreases. This feature is taken advantage of in the running of locomotives, in order to secure greater economy in the use of steam.

STERRO METAL. Sterro metal is the name formerly used for an alloy consisting of about three parts of copper to two parts of zinc, with small percentages of iron and tin. This alloy is generally known as "Delta metal."

STIEFEL PROCESS. In the Stiefel process of producing seamless tubes a heated billet is passed between the faces of two parallel disks which impart to it a rotary and a forward motion, thereby forcing the billet over and against a piercing mandrel. The working faces of the disks are shaped in such a manner as to cause a uniform speed of rotation, so that the parallel longitudinal arrangement of the fibers is not disturbed.

STOCKING CUTTERS. Roughing cutters which are intended primarily for removing surplus stock are sometimes classed as "stocking cutters" for example, when the pitch of a gear is large enough to warrant taking both roughing and finishing cuts, a "stocking cutter" may be used for removing the bulk of the metal, leaving a small amount on the sides of the teeth for finishing. Several different types of stocking or roughing cutters are in use.

STOKERS. Mechanical stokers are used extensively in steam power plants of large size. The advantages derived from their use are economy in operation, one man being able to care for several boiler furnaces; more even firing; better combustion; the introduction of fuel with a closed furnace door; and practically smokeless combustion. The principal objection to mechanical stokers is their first cost, but, in plants of large size, this objection is easily offset by the greater efficiency and by the reduction in the cost of operation. The principal considerations in the design of a mechanical

stoker are the prevention of coking of green coal; the provision for adequate mixture and heating of volatile matter with air; the burning of fixed carbon; the disposal and dumping of ash and clinker; the prevention of sifting; and the prevention of the adherence of clinker to the brickwork and the stoker parts. Stokers are divided into two general classes known as *over-feed* and *under-feed*. In the former type, the coal is fed through an opening which takes the place of a furnace door in an ordinary hand-fired furnace, and is placed on the surface of the fuel bed. In the under-feed type, the fuel is forced into the bottom of a special retort or series of retorts. A third class of stokers used for burning a certain class of bituminous coal, high in volatile matter and high in ash, is known as the *chain-grate stoker*. This type is, however, strictly speaking, only a special form of the over-feed stoker.

STONE-SAWING STRAND. For sawing blocks of sandstone, limestone, or similar soft stone, a wire strand made by twisting three wires together is used. The sand-sawing strands should not be used for sawing marble or granite, as they are not suitable for these harder stones. The strands are made in five different sizes, varying from $\frac{1}{8}$ to about $\frac{7}{32}$ inch in diameter, the approximate gage of the wires used varying from No. 16 to No. 12 steel wire gage.

STONE'S ENGLISH GEAR BRONZE. This bronze is very serviceable for gears and worm-wheels. See Copper-tin Alloy.

STOP MECHANISM, "BEAVER-TAIL." See "Beaver-tail" Stop.

STOP-PINS FOR DIES. The stop-pin on a die is a device for controlling the position of the stock as it is fed through for each successive stroke of the press, so that the spacing of the openings cut into the stock will be uniform and a predetermined distance apart. There are many different types of stop-pins, such as the plain fixed stop-pin, the bridge stop-pin, the simple latch, the spring toe latch, the side swing latch, the positive heel-and-toe latch, etc. These devices, with the exception of the first, can be used with either hand feed or automatic roll feed.

STORAGE BATTERIES. Secondary or storage batteries are devices which transform chemical into electrical energy which can be restored again after having been consumed. The unit of the battery is the cell, that is, a jar or retainer containing positive and negative plates (*electrodes*) and a conductive liquid (*electrolyte*). The voltage of a cell depends upon the electro-chemical properties of the materials used for electrodes and electrolyte, and is independent of the size of the electrodes or the quantity of the electrolyte; the current capacity of a cell is dependent upon the surface of the electrodes submerged in the electrolyte. Several cells together form a *battery*. When after a discharge an external source of electrical energy is

connected to the battery, and current is forced through it in the direction opposite to that taken by the discharge current, the electrochemical process of the discharge is reversed and the battery is gradually brought back to the same condition it was in when the discharge started. This process is called *charging* the battery. The input during charge must be somewhat greater than the output required at discharge, on account of various internal losses and on account of polarization. The rate of discharge of a storage battery is the *number of amperes* that it will supply continuously for a given time. All charging should be done at the rates given by the manufacturer. Only direct current can be used to charge storage batteries.

STORAGE BATTERY HISTORY. Gaston Planté in 1860 made the first practical storage battery. This battery was provided with lead plates immersed in a 10 per cent solution of sulphuric acid in water. Credit for a most important storage battery development belongs to Camile A. Faure, whose United States patent was issued in 1882. In this battery the lead plates were covered with red lead, which on the negative plate was reduced to a metallic lead, while on the other plate it was oxidized to a state of peroxide, due to passage of a current of electricity. These actions were reversed when the charged battery was discharging current. The Faure battery consisted of alternate layers of sheet lead and a paste of red oxide of lead, all immersed in a 10 per cent solution of sulphuric acid in water. Subsequently hundreds of patents were issued to different inventors covering various improvements. Patents granted to Brush in 1882 and 1883 covered notable improvements.

STORAGE BATTERY RATINGS. The following S. A. E. standard specifications are applied only to lead-acid storage batteries for automotive equipment. Batteries for combined starting and lighting service shall have two ratings. The first rating shall indicate the lighting ability and shall be the capacity in ampere-hours of the battery when it is discharged continuously at the 20-hour rate to a final voltage of not less than 1.75 per cell, the temperature of the battery at the beginning of such discharge being 80 degrees F. The second rating shall indicate the starting ability and shall be the minimum amperes when the battery is discharged continuously at the 20-minute rate to a final voltage of not less than 1.5 per cell, the temperature of the battery at the beginning of such discharge being 80 degrees F.

STOVE BOLT. This bolt has been so named because of its use in stove building. It is made in a number of different forms, either with a round button, or flat countersunk head, the head having a slot for a screwdriver and the threaded end being provided with a square or hexagon nut.

STOVE-BOLT TAPS. There is no standard for stove-bolt taps that has been accepted by all the different makers, and the diameters of taps made by

different manufacturers vary to a great extent. According to common practice the thread has an angle of 60 degrees, with an arbitrary flat on the top, and a flat at the bottom corresponding to that of the standard U. S. thread for pitches coarser than the actual number of threads per inch in the tap.

STOVE COAL. This coal is in pieces of such size that they will not pass a screen of $1\frac{3}{8}$-inch mesh, but will pass a screen of 2-inch mesh.

STRADDLE MILLING. When it is necessary to mill opposite sides of duplicate parts so that the surfaces will be parallel, two cutters can often be used simultaneously. This is referred to as *straddle milling*. The two cutters which form the straddle mill are mounted on one arbor, and they are held the right distance apart by one or more collars and washers. Side-mills which have teeth on the sides as well as on the periphery, are used for work of this kind.

STRAIGHTEDGES. Straightedges are used to test flat surfaces for determining whether or not they are true planes, and also for testing round parts for bends, or curvatures in a lengthwise direction. A common form of machinists' straightedge is of rectangular section. In order to increase the sensitiveness of a straightedge for showing minute deviations or curvatures, the testing edge is made narrower by beveling one side, thus decreasing the width to about $\frac{1}{16}$ inch. For work requiring extreme accuracy, the type known as a *knife-edge* straightedge is used. The testing edge is very narrow and is of semicircular cross-section so that a line contact is obtained instead of a surface contact, as with the form having flat edges. This line contact shows any minute curvature which may exist, and as the edge is curved, the accuracy of the test will not be affected if the straightedge is not held exactly at right angles to the surface being tested.

STRAIGHT-LINE MOTIONS. A combination of links arranged to impart a rectilinear motion to a rod or other part independently of guides or ways is known either as a *straight-line* motion or a *parallel* motion, the former term being more appropriate. Mechanisms of this type were used on steam engines and pumps of early designs to guide the piston-rods, because machine tools had not been developed for planing accurate guides. The principal application of straight-line motions at the present time is on steam engine indicators for imparting a rectilinear movement to the pencil or tracing point. Very few straight-line mechanisms produce a motion which is absolutely straight, and the general practice is to so design them that the guided part will be on the line when at the center and extreme ends of the stroke.

STRAIGHT-SIDED POWER PRESSES. Presses of this type have neither a gap nor arch in the frame but, as the name implies, has a straight-

sided frame. This style is suitable for heavy blanking, piercing, forming, redrawing, reducing, and bending. This type of press was originally designed for trimming drop-forgings while either hot or cold. What are known as *straight-sided trimming presses* are equipped with side cut-off attachments consisting of an outer slide operated by a pitman connecting with a crank at the outer end of the main crankshaft. This outer slide may be used either for punching holes or for cutting off and trimming. Embossing is often done on straight-sided presses. The term " straight-sided " also implies that the press has a single crank.

STRAIN THEORY, MAXIMUM. See under Stress Theories.

STRANDED CONDUCTOR. In electricity, this is a conductor composed of a group of wires or a combination of groups of wires twisted or braided together, but not insulated from one another. One wire or group of wires in a stranded conductor is a *strand.*

STRANDED CONDUCTOR SIZES. According to the Standardization Rules of the American Institute of Electrical Engineers, the sizes of solid wires shall be stated by their diameter in mils, the American Wire Gage (Brown & Sharpe) sizes being taken as standard. The sizes of stranded conductors shall be stated by their cross-sectional area in circular mils. For brevity, in cases where the most careful specification is not required, the sizes of solid wires may be stated by the gage number in the American Wire Gage, and the sizes of stranded conductors smaller than 250,000 circular mils (*i.e.*, No. 0000 A.W.G. or smaller) may likewise be stated by means of the gage number in the American Wire Gage of a solid wire having the same cross-sectional area. Furthermore, an exception is made in the case of " flexible stranded conductors." (Conductors of special flexibility should ordinarily be made with wires of regular A.W.G. sizes, the number of wires and size being given. The approximate gage number or approximate circular mils of such flexible stranded conductors may be stated.) In stating large cross-sections, it is sometimes convenient to use a circular inch (507 sq. mm.) instead of 1,000,000 circular mils.

STRANDED WIRE. A group of small wires, used as a single wire is called a " stranded wire." There is no sharp dividing line of size between a stranded wire and a cable. If used as a wire, for example in winding inductance coils or magnets, it is called a " stranded wire " and not a cable. If it is substantially insulated, it is called a " cord."

STRAP CAM. This is a cam often used for the operation of automatic screw machines, in which guide strips or straps are bolted to a cylindrical drum in order to provide the required cam surface. The object of the strap cam is to make it possible to easily change the action of the cam by moving

the straps to different positions on the drum or by replacing them when a different shape is required.

STRENGTH OF MATERIALS. See kind of material.

STRESS DEFINITIONS. A *stress* is a force acting within a material or machine part resisting deformation. A load tends to produce deformation and is resisted by the stress which it creates within the body. A *working load* is the maximum load applied to a material under ordinary working conditions. A *working stress* is the stress produced in the material by the working load. A *safe working stress* is the maximum permissible working stress under given conditions, as, for example, for a certain material. The *total stress* is the sum of all the stresses caused at one section of the body, irrespective of its area in square inches; whereas the terms *stress*, *working stress*, or *intensity of stress* generally mean the number of pounds stress per square inch of section.

STRESSES, COMPOUND. See Compound Stresses.

STRESSES, FATIGUE. See Fatigue Stresses.

STRESS THEORIES. If a part must be designed to withstand compound stresses, it is essential to consider the combined effect of such stresses upon the safe-load capacity of whatever part is being designed. Opinions differ, however, as to the theory upon which formulas for combined stress calculations should be based. Three principal theories have been advanced. These are (1) the maximum strain theory; (2) the maximum stress theory; and (3) the maximum shear theory. Formulas based upon all of these theories are in use, and while the results obtained by these formulas may differ considerably, the factor of safety is ordinarily large enough to more than compensate for whatever differences or inaccuracies may be due to the particular formula employed. It does not follow, however, that these different formulas for compound stresses may be used interchangeably for all classes of work. For example, a formula based upon the maximum shear theory applies only to ductile material, such as steel, and would be unsuitable for cast iron. It is claimed, however, by some investigators that the maximum shear theory for its particular field of application is more accurate than the older theories.

Maximum Strain Theory. — According to the maximum strain theory, failure occurs when the maximum unit deformation or strain in the piece reaches a certain critical value; hence, the stresses as measured by deformations or the "true stresses" should be considered. In other words, this theory supposes that the thing which causes failure and which must be used as a criterion for safety is the amount of deformation or strain. With a modulus of elasticity, E, of 30,000,000 there is a deformation or strain of

0.001 inch in every inch of length with a simple stress of 30,000 pounds. If now 30,000 pounds is the elastic limit, then when we have compound stresses, failure will begin to occur whenever the net strain due to the action of all the stresses together becomes 0.001 inch per inch. This theory is generally credited to Saint-Venant but he attributed it to Mariotte. It is used to a considerable extent in Europe, and to some extent in the United States.

Maximum Stress Theory. — The maximum stress theory supposes that failure and elastic limit are purely matters of stress in a given direction regardless of the existence of stresses in other directions. That is to say, if a stress of 30,000 pounds is the elastic limit for a simple stress in a testing machine, it will also be the elastic limit in any case of compound stresses if the stress in one direction is 30,000 pounds and regardless of the existence of lesser stresses, whether tension or compression, in directions at right angles. According to Rankine, the yielding of a material subjected to combined stresses depends entirely upon the maximum apparent normal stress, and is independent of the apparent shear or other stresses which may act at right angles to it. It has been established, however, that ductile materials such as shafting steels generally fail in shear and not in tension or compression, the latter being the fundamental assumption of the maximum-principal-stress theory; consequently this maximum stress theory cannot be applied to such cases. For brittle materials, on the other hand, failure may, or may not take place in tension and this theory or a modification thereof may apply.

Maximum Shear Theory. — The third and more modern theory of elastic failure is based on the fundamental assumption that the maximum intensity of shear in a ductile material is the factor which determines elastic failure. This maximum-shear theory agrees very nearly with the results of tests for ductile materials and is coming more and more into favor. Any case of direct tension or compression produces a tendency to slide and the failure is due to this. A compression failure illustrates this directly. A tension failure if carefully examined will show the same point. It was also known for many years before Guest's publication of the maximum shear theory, that at about the time the elastic limit was reached in a tension specimen, lines at an angle of 45 degrees began to appear, indicating failure by shear. This indicates that failure by tension and failure by compression are really only different aspects of failure by shear. Failure means the beginning of sliding which is not recovered when the stress is removed and gives permanent set, thus indicating the "elastic limit." It follows, therefore, that the elastic limit will be the same for tension as for compression. This is true for steel and other ductile materials and is in itself a point of evidence in favor of the maximum shear theory.

Cast iron has no elastic limit and the actions referred to do not occur, so

that elastic failure does not exist in cast iron as called for by the maximum shear theory. As is well known, the action of cast iron is quite different in tension and compression. Some experimental work on cast iron indicates that rupture with compound stresses occurs when the maximum stress reaches the value causing rupture with simple tension. This, of course, may not mean that a safe compound stress with cast iron occurs when the maximum stress reaches the safe value for tension.

Rules for Maximum Shear Theory. — The following rules should be used in determining failure according to the maximum shear theory.

When there are stresses in two directions at right angles, with no stress in the third direction, and with both stresses of the same kind, that is, both compression or both tension, the equivalent simple stress is equal to the greater of the two stresses. In this case the maximum stress theory gives exactly the same results.

When there are stresses in two directions at right angles, with no stress in the third direction, and with the stresses of opposite kinds, that is, one tension and one compression, the sum of the numbers giving the two stresses gives the equivalent simple stress. That is to say, if we have tension of 10,000 pounds in one direction and compression of 5000 pounds in another direction, the situation so far as failure is concerned is exactly the same as if we had a simple stress in a testing machine of 15,000 pounds per square inch.

When there are stresses in all three directions at the same time and all of the same kind, that is, all tension or all compression, we subtract the minimum from the maximum of the three stresses to obtain the equivalent simple stress.

When there are stresses in three directions at the same time, one or more tension and one or more compression, the sum of the numbers giving maximum compression and maximum tension stress gives the greatest equivalent simple stress.

In the case of a beam at the point of maximum stress there is usually stress in a single direction, so that this stress is a simple one and we need make no use of the maximum shear theory. In case of a rotating shaft subject to bending and twisting at the same time, that bending moment, which, if existing alone, would give the same conditions so far as failure is concerned, is the square root of the sum of the squares of the actual bending and twisting moments as shown by the Guest formula. This is also equal to that twisting moment which, if existing alone, would give the same conditions so far as failure is concerned. In the case of a rotating wheel, such as a turbine disk, there are radial and tangential stresses which are both tensile stresses; hence, the greater of the two gives the equivalent simple stress, the same as if the maximum stress theory were used.

STRIKING POINTS. Striking points are marks made on the guide of an engine to show where a special mark made on the crosshead would register with them if the connecting-rod was of such length that the piston would just strike the cylinder head at the corresponding end of the stroke. Striking points are useful for determining readily the amount of piston clearance obtained at each end of the stroke after keying up the connecting-rod, by placing the engine first on one dead-center and then on the other.

"STRIKING" SCISSORS. After nickel plating scissors, the blades are buffed and the two mates assembled. The last operation on the assembled scissors is that of "striking" the edges of the blades, or in other words, sharpening the scissors by grinding.

STRING FORGING. String forging is the process of forging a number of similar parts at once by means of dies having a number of depressions side by side. The method is generally employed for the forging of ball blanks, a string of which are thus forged at once in dies having a number of semi-spherical depressions.

STRING MILLING FIXTURE. The term "string milling fixture" is often applied to that class of fixture in which the castings are placed in a row on the milling machine table, extending in a direction parallel to the line of travel of the table. With such an arrangement, provision is made for milling all of the castings with a single cutter, or gang of cutters, mounted on the arbor. In some cases, however, it may be found more desirable to set up the work in fixtures that provide for holding the castings or forgings side by side, instead of end to end.

STRIPPER PLATES. When punches and dies are used to perforate sheet stock, the latter will be carried upward when the punch ascends, unless there is some device to prevent this. The simplest arrangement for stripping the stock from the punch and one that is applied to most blanking dies, consists of a plate which is attached to the die and has an opening for the punch to pass through. Beneath this stripper plate there is a passage-way or opening through which the stock is fed. Obviously, the space between the die-face and stripper plate must be greater than the thickness of the stock in order to permit the latter to be fed along easily. As the result of this play between the stripper plate and the die, the stock is distorted to some extent by the action of the punch. This distortion, in many cases, does not cause trouble, especially when the die simply cuts out plain blanks, but when a follow die is used and flat accurate blanks are required, or when the operation is that of piercing a number of holes in sheets or flat plates, it is often necessary to hold the stock firmly against the die while the punches pass through it, in order to prevent any wrinkling or buckling.

Stripper Attached to Punch. — One method of preventing the stock from being wrinkled or distorted by the action of the punch consists in attaching the stripper plate to the punch-holder instead of to the die. The stripper plate is backed up by a stiff coil spring at each corner, and on the downward stroke of the press, it presses the stock firmly against the die, holding it level while the punches perform their work. The stripper is so located that the punches do not come quite flush with its lower face, so that the stock is subjected to pressure before the punches come into action.

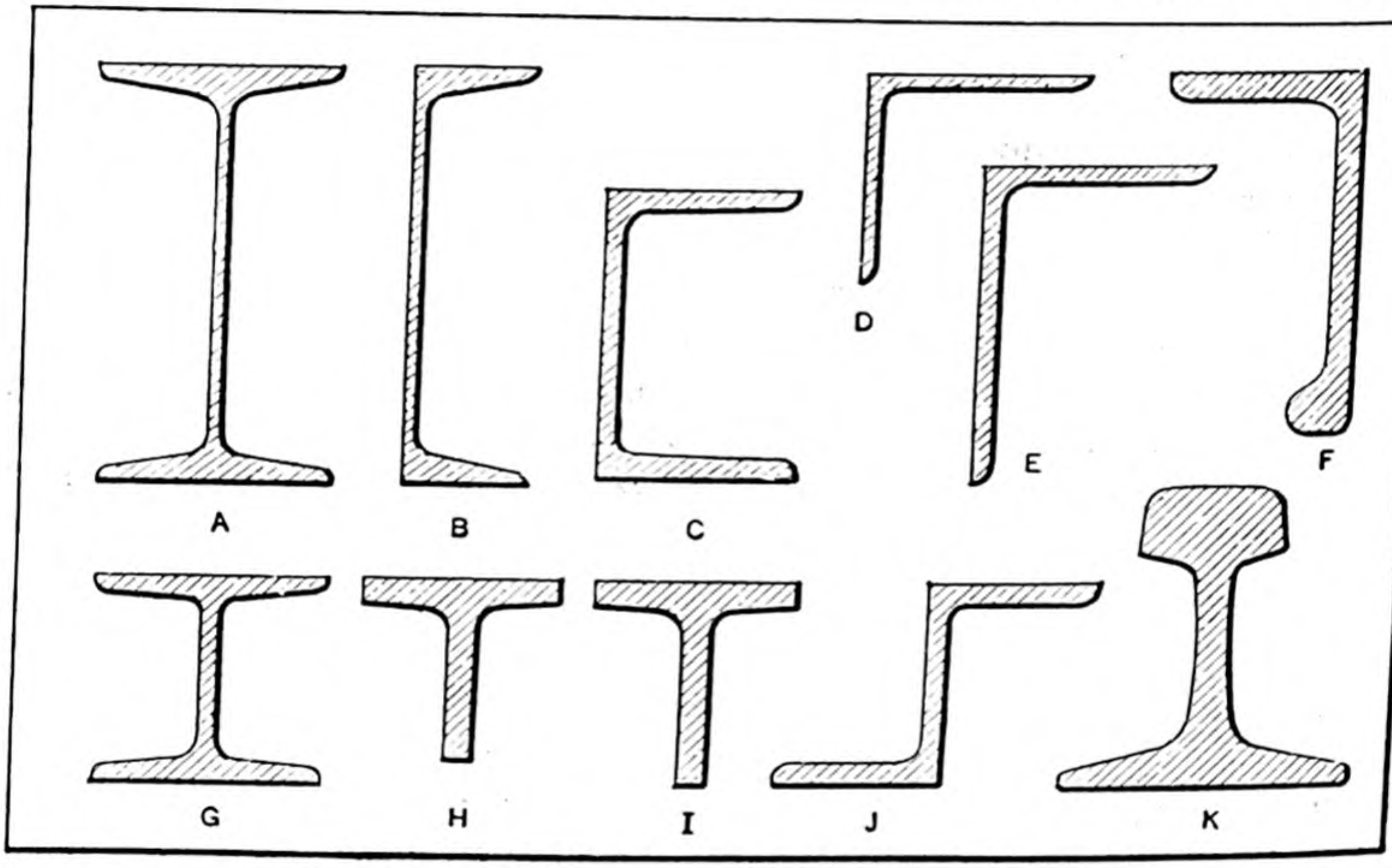
Stripper Plates of Cam-operated Type. — Owing to the tendency that stationary stripper plates attach to dies have to distort pierced sheets, etc., some presses are equipped with cam-actuated stripper plates. The stripper plate is attached to vertical rods which extend up above the press slide. When the press is in operation, the stripper, which is actuated by cams on the press shaft, descends first and clamps the stock before the punches enter the work. As the stripper plate is suspended above the die, a clear space is left between the punch and die, so that the operator has an unobstructed view. The stripper plate moves up and down with the punches, so that the latter can be made shorter than would be possible with a stationary stripper, thus increasing their rigidity and durability. This method of stripping the stock is particularly adapted for gang punching and perforating operations, especially when the punches are small in proportion to the thickness of the stock and when it is essential to guide them close to the surface of the work.

STROBOSCOPE. The stroboscope is an instrument, by the aid of which an observer may examine a point on a fast revolving mechanism, by a series of quick successive glimpses at that point, thus giving the mechanism the effect of being stationary. During the brief period of each glimpse, an impression is made on the retina of the eye, which remains until it is followed by the next glimpse, the whole succession of glimpses being woven into a continuous picture; this phenomenon is known as "persistance of vision."

The earliest form of stroboscope consists of a disk with a single hole in it, the disk being rotated in front of the mechanism to be examined, and at the same speed as the mechanism. Once every revolution the hole will come in the line between the observer's eye and the mechanism, giving the stationary effect. Another method of interrupting the vision is by means of a vibrating reed, such as the limb of a tuning fork, with a shutter on the end of it, the reed being maintained in vibration electrically at the same frequency as the rotation of the mechanism under observation. In order to obtain a clearly defined stationary image, the duration of each glimpse must be extremely short, as otherwise the mechanism will have time to move an appreciable amount during the actual period of observation. See also Vibroscope.

STRONTIUM. Strontium is one of the metallic chemical elements, the symbol of which is Sr, and the atomic weight, 87.63. The metal has a silver-white color. The specific gravity is 2.54. The melting point is at 830 degrees C. (1525 degrees F.). Strontium is found in small quantities in various rocks and soils, and in mineral waters. It is a ductile metal which oxidizes rapidly in the air and which burns when heated in the air or in oxygen.

STRUCTURAL SHAPES. Steel rolled to standard sections is widely used in building construction and in the manufacture of railway cars, agricultural implements, automobiles and numerous other products. By using a standard shape which is on the market and is adapted to a given



Structural Steel Shapes Commonly Used

structure or design, it is often possible to secure a stronger, lighter construction and a reduction of manufacturing cost. Shapes which have been widely used are shown in the accompanying illustration. There are many other more or less special shapes for use in the agricultural, automotive, railway car, ship-building and other large industries.

Structural Beams. — The structural or I-beam section is shown at *A*. The depths of these beams ordinarily range from 3 to 24 inches, although these figures and others to follow are intended to give a general idea of the minimum and maximum sizes ordinarily rolled, but they do not in all cases represent the absolute limits. The weights per foot vary from 5.7 pounds to 120 pounds for the small and large sizes mentioned. Each size, how-

ever, is made in different weights. There is also some variation in flange widths.

Channels. — Structural channels (*B*), ordinarily range in depth from 3 to 18 inches, with weights per foot varying from about 4 to 58 pounds. Each channel size is made in three or four different weights. There is also some variation in flange widths. Ship-building channels have the same general shape as the structural channels but are somewhat lighter. Car-building channels (*C*) have wider flanges in proportion to the depth.

Angles. — Equal angles (*D*) vary ordinarily in size from 1 by 1 inch up to 8 by 8 inches. The small size varies in weight from 0.8 to 1.49 pounds per foot, and the 8 by 8-inch size from 26.4 to 56.9 pounds per foot. Unequal angles (*E*) vary from $1\frac{1}{4}$ by $1\frac{1}{2}$ inches up to 6 by 8 inches and each size is made in a wide range of weights. "Square root" angles are similar to equal angles except that each section of the former is rectangular, there being no fillet at the intersection or rounding of the outer corners.

Bulb Angles. — Ship-building bulb angles (*F*) range from a $2\frac{1}{2}$ by $1\frac{1}{2}$-inch size up to the 10 by $3\frac{1}{2}$-inch size. The minimum size mentioned weighs 2.66 pounds per foot and the large sizes either 33.2 or 35.2 pounds per foot. All except the very small sizes are made in two or three different weights.

H-beams. — An H-beam section (*G*) is similar to the I-beam except that the flange width is equal to the beam depth. One large steel mill lists a minimum size of 4 by 4 inches and a maximum size of 8 by 8 inches.

Tees. — Equal tees (*H*) range in size from 1 by 1 inch up to $6\frac{1}{2}$ by $6\frac{1}{2}$ inches, and with weights per foot of 0.89 pound and 19.8 pounds, respectively, for the two sizes mentioned. Unequal tees (*I*) may have a flange width which exceeds the stem (vertical section) depth, or this order may be reversed.

Zees. — The flange widths and web heights of zees (*J*) range from $2\frac{11}{16}$ by 3 inches up to $3\frac{1}{2}$ by 6 inches. The smallest zee mentioned weighs either 6.7 or 8.5 pounds per foot and the largest, from 29.4 to 34.6 pounds per foot. There are three different weights for each size excepting the very small sizes.

Rails. — The American Railway Association rails (section *K*) vary in depth from $4\frac{1}{2}$ to 6 inches; in base width, from 4 to $5\frac{1}{2}$ inches; in head width, from $2\frac{1}{4}$ to $2\frac{3}{4}$ inches; and in weight from 60 to 100 pounds per yard. "Light rails" vary in depth from $1\frac{9}{16}$ inches to $3\frac{11}{16}$ inches and in weight, from 8 pounds to 45 pounds per yard.

STRUCTURAL STEEL. Under the heading structural steel are included steels made either by the open-hearth or the Bessemer process, rolled to standard shapes suitable for structural purposes, and containing a smaller amount of carbon than that usually found in crucible or tool steel.

Structural Alloy Steels. — When plain carbon steels are used for construction purposes, chemical analysis and tensile tests prove, in general, a fairly

satisfactory indication of suitability, especially when the question of weight of construction is not of particular importance; however, the advent of high-powered machinery, and especially of automobiles and airplanes, has resulted in a demand for material that will withstand exceptionally high stresses, and the question of lightness is of prime importance. These demands have created a wide market for alloy steels which, incidentally, are used nearly always in the heat-treated condition. The study of alloy steels, and the specific influence of the metals entering into them involves, in addition to chemical and tensile tests, microscopic methods of examination, impact tests, vibratory tests, and various other tests, the object in each case being to reveal some new information that will assist the engineer in designing for maximum efficiency and light weight.

STRUCTURES, VIBRATION. See Vibration of Structures.

STRUT. In engineering, a strut is a structural member the length of which is considerable in proportion to its width, depth, or diameter. See Column.

STUB'S IRON WIRE GAGE. Same as Birmingham Wire Gage.

STUB'S STEEL. Stub's steel is used for small pins, studs, shafts, screws, etc., requiring strength and toughness. It can be easily machined and hardened, and has a bright finish. As a general rule, stub's steel may economically be used where the largest diameter does not require further machining. Weight, 0.283 pound per cubic inch; 489 pounds per cubic foot. Specific gravity, 7.85. Strength: tension, 70,000 pounds per square inch. Melting point, 2600 degrees F.

STUB'S STEEL WIRE GAGE. This gage is used for drawn steel wire or drill rods of Stub's make, and also by a number of American drill rod manufacturers. It differs from Stub's iron wire gage which is the same as the Birmingham Wire Gage. The gage sizes may be found in MACHINERY'S Handbook.

STUB-TOOTH GEARS. Most gears used in general machine construction, and excepting those used in automobile transmissions and for certain special applications, have a pressure angle of $14\frac{1}{2}$ degrees and a whole tooth depth equal to 2.157 divided by diametral pitch. The stub-tooth form has about 0.8 of the "standard depth" obtained by the formula just given, and the pressure angle of stub-tooth gears is 20 degrees. Consequently, stub teeth are much stronger than those of greater depth and smaller pressure angle and the comparative increase in strength is greater for the smaller stub-tooth gears; moreover, important advantages in regard to tooth action are claimed for stub-tooth gears, although there are wide differences of opinion concerning the practical results.

Fellows System. — The stub gear teeth introduced by the Fellows Gear

Shaper Co. are based on the use of two diametral pitches. One diametral pitch, say, 8, is used as the basis for obtaining the dimensions for the addendum and dedendum, while another diametral pitch, say, 6, is used for obtaining the dimensions of the thickness of the tooth, the number of teeth, and the pitch diameter. Teeth made according to this system are designated as $\frac{6}{8}$ pitch, $\frac{12}{14}$ pitch, etc., the numerator in this fraction indicating the pitch determining the thickness of the tooth and the number of teeth, and the denominator, the pitch determining the depth of the tooth. The clearance is made greater than in the ordinary gear-tooth system and equals 0.25 ÷ diametral pitch. The pressure angle is 20 degrees.

Nuttall System. — In a system of stub gear teeth originated by C. H. Logue of the R. D. Nuttall Co., the tooth dimensions are based directly upon the circular pitch. The addendum is made equal to 0.250 × the circular pitch, and the dedendum equal to 0.300 × the circular pitch. The pressure angle is 20 degrees.

Power Transmitting Capacity. — In applying the Lewis formula to stub-tooth gears, the outline or strength factors given in the accompanying table may be used. This table covers both the Fellows and the Nuttall systems. If H = number of horsepower a gear will safely transmit; S = allowable unit stress for gear material at given velocity; A = face width in inches; Y = strength factor; P^1 = circular pitch; V = pitch-line velocity in feet per minute, then $H = \frac{SAYP^1V}{33,000}$. If the stub teeth are based on the Fellows system, the circular pitch is equivalent to the diametral pitch in the numerator of the fraction. For example, if a stub-tooth gear is of $\frac{4}{5}$ pitch, the circular pitch is equivalent to 4 diametral pitch, or 0.7854. The value S for different velocities and materials will be found in MACHINERY'S Handbook in connection with the general subject of horsepower of spur gearing. Stub-tooth gears of the Nuttall system are based directly upon the circular pitch.

Pitch for Given Horsepower. — If the horsepower formula previously given is transposed in order to find the circular pitch, we have $P_1 = \frac{H.P. \times 33,000}{SAYV}$. In using this formula in connection with the Fellows system, the object is to determine what circular pitch P_1 is equivalent to a diametral pitch in the numerator of one of the series of pitches seen at the top of the table of factors Y, but in order to use the formula as it stands we must know the value of Y, and this cannot be determined unless we know the pitch, as well as the number of teeth. Thus we have two unknown factors and the formula may be written as follows:

$$P_1Y = \frac{H.P. \times 33,000}{SAV}.$$

Strength Factors Y for Stub-tooth Gears

No. of Teeth	Fellows System								Nuttall System
	4/5	5/7	6/8	7/9	8/10	9/11	10/12	12/14	
12	0.096	0.111	0.102	0.100	0.096	0.100	0.093	0.092	0.099
13	0.101	0.115	0.107	0.106	0.101	0.104	0.098	0.096	0.103
14	0.105	0.119	0.112	0.111	0.106	0.108	0.102	0.100	0.108
15	0.108	0.123	0.115	0.115	0.110	0.111	0.105	0.103	0.111
16	0.111	0.126	0.119	0.118	0.113	0.114	0.109	0.106	0.115
17	0.114	0.129	0.122	0.121	0.116	0.116	0.111	0.109	0.117
18	0.117	0.131	0.124	0.124	0.119	0.119	0.114	0.111	0.120
19	0.119	0.133	0.127	0.127	0.122	0.121	0.116	0.113	0.123
20	0.121	0.135	0.129	0.129	0.124	0.123	0.118	0.115	0.125
21	0.123	0.137	0.131	0.131	0.126	0.125	0.120	0.117	0.127
22	0.125	0.139	0.133	0.133	0.128	0.126	0.122	0.118	0.128
23	0.126	0.141	0.134	0.135	0.129	0.128	0.123	0.120	0.130
24	0.128	0.142	0.136	0.136	0.131	0.129	0.125	0.121	0.131
25	0.129	0.143	0.137	0.138	0.133	0.130	0.126	0.123	0.133
26	0.130	0.145	0.139	0.139	0.134	0.132	0.128	0.124	0.134
27	0.132	0.146	0.140	0.140	0.135	0.133	0.129	0.125	0.136
28	0.133	0.147	0.141	0.141	0.136	0.134	0.130	0.126	0.137
29	0.134	0.148	0.142	0.143	0.137	0.135	0.131	0.127	0.138
30	0.135	0.149	0.143	0.144	0.138	0.136	0.132	0.128	0.139
32	0.137	0.150	0.145	0.146	0.140	0.137	0.134	0.130	0.141
35	0.139	0.153	0.147	0.148	0.143	0.139	0.136	0.132	0.143
37	0.140	0.154	0.149	0.149	0.144	0.141	0.138	0.133	0.145
40	0.142	0.156	0.151	0.151	0.146	0.142	0.140	0.135	0.146
45	0.145	0.159	0.154	0.154	0.149	0.145	0.142	0.138	0.149
50	0.147	0.161	0.156	0.156	0.151	0.147	0.144	0.140	0.151
55	0.149	0.162	0.157	0.158	0.152	0.149	0.146	0.141	0.153
60	0.150	0.164	0.159	0.159	0.154	0.150	0.148	0.143	0.154
70	0.153	0.166	0.161	0.161	0.156	0.152	0.150	0.145	0.157
80	0.155	0.168	0.163	0.163	0.158	0.154	0.152	0.147	0.159
100	0.158	0.171	0.166	0.166	0.160	0.156	0.154	0.150	0.161
150	0.162	0.174	0.170	0.169	0.164	0.160	0.158	0.154	0.165
200	0.164	0.176	0.172	0.171	0.166	0.162	0.160	0.156	0.167
Rack	0.173	0.184	0.179	0.176	0.172	0.170	0.168	0.166	0.175

To show how this equation may be applied, assume that the problem is to determine the pitch, according to the Fellows system, for a gear having 20 teeth, a velocity of 600 feet per minute, face width of $2\frac{1}{2}$ inches, and with an assumed working stress of 10,000. The gear is to transmit 43 horsepower. We have then,

$$P_1 Y = \frac{43 \times 33{,}000}{10{,}000 \times 2\frac{1}{2} \times 600} = 0.0946 \cdot$$

The next step is to determine, by trial, what factor Y multiplied by the circular pitch, is equivalent to 0.0946. Referring to the table of outline factors Y, suppose we try $\frac{6}{8}$ pitch. The circular pitch equivalent to 6 diametral pitch is 0.5236, but to simplify the work divide 0.0946 by 0.5, thus obtaining the quotient 0.189. Now by referring to all of the factors Y for 20 teeth, it will be seen that none are as high as 0.189; hence, it is evident that we should try some other pitch. Perhaps two or three trials may be

necessary, but assume that $\frac{4}{5}$ pitch is finally selected. The equivalent circular pitch in this case is 0.7854 or about 0.78 and $0.0946 \div 0.78 = 0.121$, which is the factor Y for 20 teeth of $\frac{4}{5}$ pitch; therefore, this pitch may be used.

If the stub-tooth were proportioned according to the Nuttall system, then in this example we know that $Y = 0.125$ because there is only one factor for 20 teeth; hence, the formula $P_1 = \dfrac{H.\ P. \times 33{,}000}{SAYV}$ could be used.

Approximate Rule for Stub-tooth Gears. — According to an approximate rule for determining the increase in power transmitting capacity of stub-tooth gears, as compared with ordinary gears, this increase may be determined in the case of the Fellows system, by merely inverting the fraction representing the pitch and multiplying by the horsepower capacity of ordinary gearing. To illustrate, if a stub-tooth gear has teeth of, say, $\frac{4}{5}$ pitch, multiply the power-transmitting capacity of an ordinary gear by $\frac{5}{4}$ to obtain the capacity of a stub-tooth gear. Thus, if a gear of 4 diametral pitch and $14\frac{1}{2}$-degree pressure angle has 20 teeth, a face width of $2\frac{1}{2}$ inches, pitch-line velocity of 600 feet per minute, and if the working stress is assumed to be 10,000, then, according to the Lewis formula, it will safely transmit 32 horsepower. To determine the increase in strength for a stub-tooth gear of $\frac{4}{5}$ pitch, we have $32 \times \frac{5}{4} = 40$ horsepower, which is nearly the same as the result obtained by the use of the formula and factors Y as applied to a similar example.

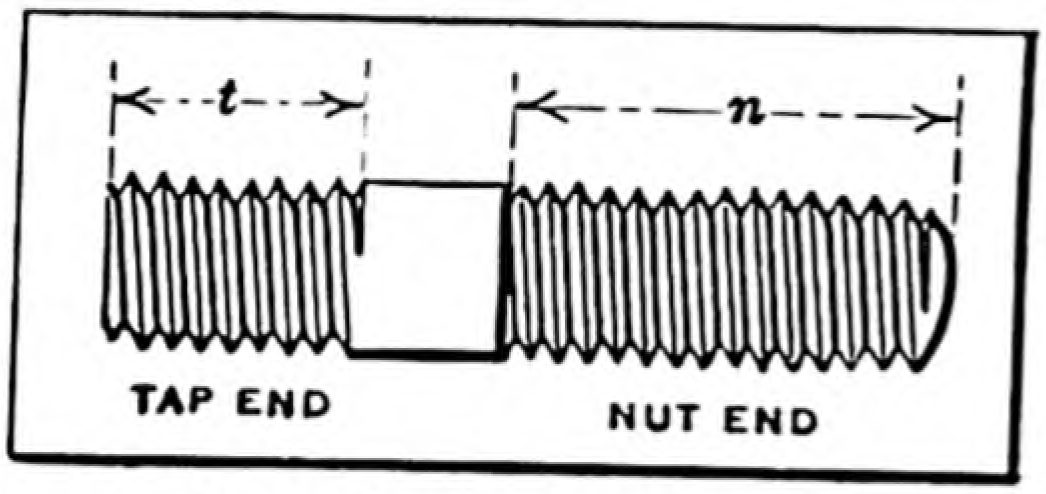
STUB-TOOTH GEARS, A. G. M. A. The stub-tooth involute gears adopted April, 1924, by the American Gear Manufacturers' Association, as recommended practice, differs from the Fellows and Nuttall stub-tooth systems. The tooth proportions, which are identical with the recommended practice for herringbone gears, may be determined by the following formulas in which D. P. = diametral pitch; C. P. = circular pitch; N = number of teeth.

Addendum = $0.8 \div$ D. P. = $0.2546 \times$ C. P.
Dedendum = $1 \div$ D. P. = $0.3183 \times$ C. P.
Working Depth = $1.6 \div$ D. P. = $0.5092 \times$ C. P.
Total Depth = $1.8 \div$ D. P. = $0.5729 \times$ C. P.
Pitch Diameter = $N \div$ D. P. = $0.3183 \times N \times$ C. P.
Outside Diameter = $(N + 1.6) \div$ D. P.

Diametral pitch is used up to 1 diametral pitch, inclusive, and circular pitch for 3 inches circular pitch and over. The pressure angle is 20 degrees. A minimum root clearance of $0.2 \div$ D. P. is recommended for new cutters and gears. There is correct tooth action between gears cut to this new system and those cut to the older Nuttall system, the only dimensions affected being the clearance. Where the proposed A. G. M. A. gear runs with a Nuttall gear, the clearance between the outside diameter of the

proposed gear and the root diameter of the Nuttall gear equals 0.1425 ÷ D. P., and the clearance between the outside diameter of the Nuttall gear and the root diameter of the proposed gear equals 0.2146 ÷ D. P.

STUDS. Studs or stud-bolts are cylindrical pieces having a thread on each end. A stud differs from a cap-screw in that a nut is substituted for a solid head. One end of a stud, as shown at *t* (see illustration), is for insertion in a tapped hole and the longer threaded end *n* is for receiving one or two nuts, a second lock-nut sometimes being used to hold the other in place. The thread on the short end is usually a little oversize to make it fit tightly into the tapped hole. The nominal length of a stud is the same as the total length. Studs are extensively used for holding cylinder heads, steam-chest covers, and similar parts in position, the nuts on the outer ends clamping the head or cover against the part into which the studs are screwed.



Stud of Common Form

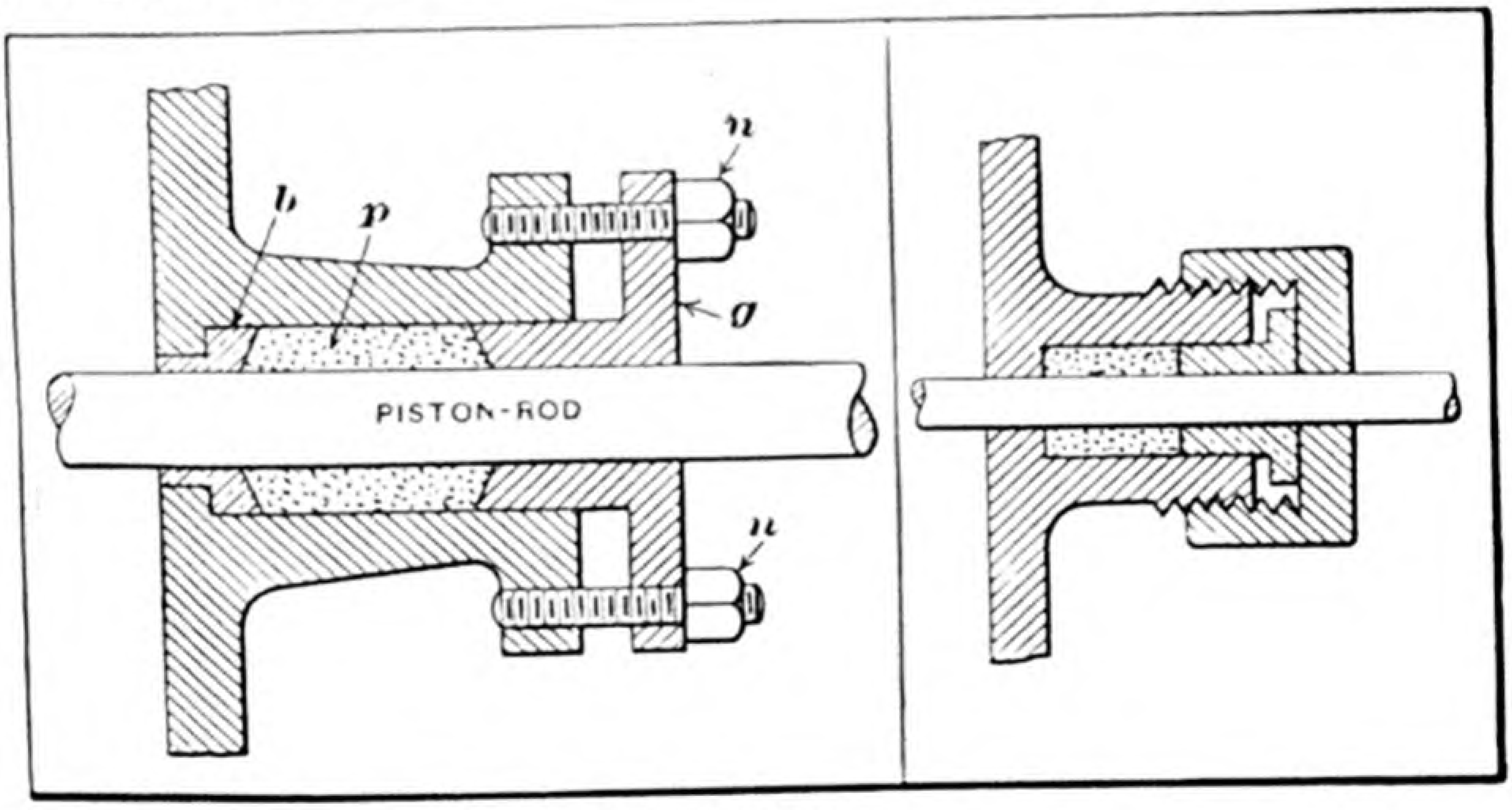
Studs and Cap-screws. — Studs are preferable to cap-screws for holding cylinder heads, covers, etc., for the following reasons: (1) A stud and nut can generally be screwed tighter than a cap-screw because of better alignment, smoother threads, and reduced effect of torsional elasticity. (2) A stud and nut are less likely to break than a cap-screw, when making repairs. In case a nut is rusted fast on a stud, it can be split with a cold chisel, but a cap-screw "sized" in the casting may be twisted off. This means that the broken part must be drilled out and a new cap-screw provided to take its place. The loss of time and extra labor incident to breakages of cap-screws are important disadvantages when making repairs. (3) Covers secured with nuts and studs can be loosened and tightened without serious deterioration of the fastening means. The nuts on studs can be loosened many times without appreciable wear of the threads, but not so with cap-screws. They soon wear the cast-iron threads and become loose and are likely to strip after being used a few times. (4) Studs have the advantage of holding gaskets in place while a cover is being applied. This is an important advantage in erecting, when the parts are heavy and applied with difficulty. (5) A stud made from a round bar is stronger than a cap-screw turned down from a hexagon bar.

STUD SETTING. The screwing of studs into the tapped holes of some part such as a steam cylinder, pump cylinder, etc., is known as *stud setting.* Studs may be screwed into place either by hand or power. Special stud-setting chucks are often employed. One type is so arranged that it can be used for either studs or nuts, and the jaws open automatically and release

either the stud or nut, as the case may be, just like a die of the self-opening type, and without stopping or reversing the spindle of the machine. There is also an adjustable friction type of chuck which must be reversed and screwed off of a stud. When setting nuts with this type, the machine must be stopped each time to disengage the holder from the nut.

STUD-THREADING MACHINES. The automatic stud-threading machine is an example of the development in the design of threading machines for high-speed operation on one class of work. This machine is intended especially for cutting the threads on studs. The number of pieces that can be threaded in ten hours with one of these machines ranges from 6900 to 39,500, the rate of production varying with the diameter of the work. This production is based on a continuous operation of the machine for the time specified.

STUFFING-BOX. This term is applied to a cylindrical chamber which surrounds a rod and is used in conjunction with a gland and holding device, for retaining packing in such a way as to prevent leakage. The left-hand



Stuffing-boxes

diagram shows a common form of stuffing-box for a piston-rod. The packing *p* is placed in a chamber surrounding the rod and is held in place by the gland *g* which may be adjusted by means of the nuts *n*. The bushing *b* is usually made of bronze, which, being softer than the rod prevents it from wear, and is easily replaced when the hole through it becomes enlarged or oval in form. The bottoms of the stuffing-box and gland are usually turned to a bevel, as shown, which has the effect of forcing the packing against the rod when soft or fibrous kinds are used. A typical stuffing-box for valve rods of small size is illustrated at the right. This is similar in construction to the one just described, except that the gland is held in place by a screw-cap instead of by bolts. The bottoms of the stuffing-box and gland are

square in this case, which is better for some of the special forms of packing now used.

SUB-BITUMINOUS COAL. This is also known as lignite, black lignite, brown coal, and lignitic coal. It is a kind of coal containing less than 50 per cent of carbon, resembling bituminous coal, it being black and shiny, but disintegrating more rapidly than bituminous coal when exposed to the air. It has a heating value per pound of combustible of from 11,000 to 13,500 B.T.U.

SUBMERGED BODY WEIGHT. See Buoyancy.

SUB-PRESS. A sub-press cannot be defined as a special class of die, but merely as a principle which may be applied in constructing different kinds of dies. The sub-press principle is simply that the upper and lower portions of the die are combined into one self-contained unit so arranged as to always hold the upper and lower members in exact alignment with each other. A common form of sub-press construction consists of a base which is clamped to the press, a frame or " barrel " fitted to the base, and a plunger which slides vertically in an adjustable babbitt bearing. The plunger head is connected to the press slide. The compound type of die is commonly used in a sub-press. The upper die is located in the plunger and the lower die in the base. This sub-press construction permits of a high degree of accuracy as it insures an accurate alignment of the various members of the die.

The sub-press die was originated in watch and clock factories for performing blanking operations requiring great accuracy, and, at the present time, dies built on the sub-press principle are employed for a great variety of work in connection with many different lines of manufacturing. Sub-presses are largely used for producing such parts as small wheels and gears and other delicate parts for clocks, watches, meters, time recorders, and other similar pieces which must be made with great accuracy and uniformity. Although, in some cases, one sub-press can be made to take several sets of punches and dies, it is customary, and generally advisable, to have a separate sub-press for each set, as one of the advantages gained in using the sub-press is in being able to quickly change from one die to another; when separate sub-presses are used this can be done by simply loosening the clamps, changing the presses and reclamping. In addition to this advantage, there is no time wasted in aligning the punches and dies; moreover, the danger of shearing the punch or die, as a result of careless alignment, is entirely eliminated. Another advantage of the sub-press, dependent in part upon the accuracy of alignment provided, and the corresponding accuracy in fitting which can be given to the cutting edges, is that the work is remarkably free from fins and burs.

SUBSTATIONS. The term " substation " is applied to a building, room, or area equipped for the conversion of electricity by means of converters or motor-generator sets; for the transformation of electric power by means of transformers; for changing the frequency; or for distribution and switching. Sometimes a single station will serve all of these purposes. It is, therefore, difficult to lay down any set rules for the design of a substation, as each individual station presents certain special problems. A substation may be of the *city*, *country*, or *portable type* and may have the apparatus located in a building or out-of-doors.

SUB-SURFACE MILLING. The term " sub-surface milling " has sometimes been applied when a tilted type of rotary milling machine is used in conjunction with an auxiliary reservoir in which cutters and work can be submerged in a bath of cooling compound while the milling operation is being performed.

SUCTION. Pumps for liquids, if located at some point above the source of supply, perform two separate operations when in use; first the water or other liquid is made to flow into the pump cylinder through a " suction pipe," and then it is forced out of the cylinder through a discharge or delivery pipe leading to any desired point. The flow of the water up to the cylinder is caused by a partial vacuum within the cylinder produced by the action either of a reciprocating piston or a rotating wheel or rotor, depending upon the type of pump. This vertical movement of the water in the pipe, or lift, is due to the fact that the atmospheric pressure on the surface of the water at the source of supply is no longer counteracted by an equal pressure inside the pipe; consequently, the water is forced upward and this is commonly referred to as " suction." The suction pipe should be free from air leaks, because a very small leak will affect the operation of the pump, especially if the lift is quite high. It is advisable to test the suction line with a pressure of at least 25 pounds per square inch. See Pump Suction; also Lift of Water Pumps.

SUCTION AND DISCHARGE PIPES. The area of the suction and discharge or delivery pipes of pumps, is based upon the velocity of flow through them. For pipes approximately 25 feet in length, the velocity of flow should not exceed 200 feet per minute; for lengths of about 50 feet, the velocity should not exceed 180 feet per minute; for lengths of 100 feet, the maximum velocity should be reduced to about 150 feet per minute; and for lengths of 125 feet, the maximum velocity should be about 125 feet per minute. The area of a pipe for a given velocity of flow may be determined by the following formula in which S_a = area of suction pipe in square inches; P_a = area of piston or plunger in square inches; S = piston speed in feet per minute;

V = velocity of flow of water through the suction pipe in feet per minute.

$$S_a = \frac{P_a \times S}{V}.$$

The velocities previously given will allow for two or three elbows, a stop valve, and a foot-valve. The area of the discharge pipe may be found by using the same formula and substituting 300 for the value of V in all cases.

SULPHATE OF LIME. Same as Calcium Sulphate.

SULPHATE OF MAGNESIA. Same as Magnesium Sulphate.

SULPHUR. Sulphur is widely distributed in nature, both in the free state and in combination. The most important deposits are in Sicily. It is found in many of the important iron ores and is, therefore, generally present in iron and steel. The sulphur contents in steel must be reduced as much as possible, because sulphur, if present in too great a percentage, injures the steel. Sulphur is one of the non-metallic chemical elements, the symbol of which is S, and the atomic weight, 32.07. Commercial sulphur forms yellow crystals, melting at 113 degrees C. (235 degrees F.), and boiling at 445 degrees C. (833 degrees F.). The specific gravity of sulphur is 2.06, and the specific heat, 0.171. Sulphur ignites in air at a temperature of 363 degrees C. (685 degrees F.). It is a poor conductor of electricity.

SULPHURIC ACID. Sulphuric acid (chemical formula, H_2SO_4), frequently also called "oil of vitriol," is a colorless liquid, when in its pure state. The commercial acid has a slightly dark tint. Concentrated acid is heavier than other acids, its specific gravity, when 98.5 per cent pure, being 1.84. The commercial acid has a specific gravity of about 1.72. When this acid is mixed with water, heat is evolved, and the mixing must be done slowly. *The acid must be added to the water and not the water to the acid*, as, in the latter case, a violent explosion is likely to occur. When pure, sulphuric acid is a dense, oily, colorless, odorless liquid with a specific gravity of 1.838 at 15 degrees C. (59 degrees F.). The specific heat is 0.330. It boils at 338 degrees C. (640 degrees F.), and, at 400 degrees C. (752 degrees F.), the vapor dissociates into sulphur trioxide and water; at 10.5 degrees C. (51 degrees F.), the acid freezes to a colorless crystalline mass. When mixed in the proportion of 4 parts of acid to 1 part of water, the temperature is raised 100 degrees C. (180 degrees F.). Sulphuric acid is exceedingly corrosive and decomposes animal and vegetable substances by the aid of heat. It has a great affinity for water and unites with it in all proportions; it unites with moisture from the atmosphere and becomes weaker when exposed. Sulphuric acid of commerce is never pure; it may contain lead

sulphate absorbed from the lead chambers during the process of manufacture, arsenic, and other substances. The acid is used, to a great extent, for pickling baths and cleaning solutions.

SUNK KEY. A sunk key, as its name implies, is sunk into a shaft. With this type of key, which is the one most commonly used, care should be taken to secure a good bearing on the sides. Ordinarily, the bearing at the top and bottom of a sunk key should be comparatively light, although, in some cases, when it is used to resist endwise movement, as well as a rotary movement, it is given a heavy bearing on all sides. The principal bearing, however, should not be, in any case, at the top and bottom, as it is then more likely to work loose than when fitted tightly at the sides.

SUPERFICIAL HARDENING. When low-carbon steel is subjected to the cyanide hardening process, a very thin but extremely hard surface is obtained, and this is known as superficial hardening. This hard outer skin may be only a few thousandths of an inch thick, and this is the important difference between superficial hardening and ordinary casehardening. See Cyanide Hardening.

SUPERHEATED STEAM. Superheated steam is produced by adding heat to saturated steam after it has been removed from contact with the water from which it was formed. This is accomplished by passing the steam through superheater coils after it leaves the boiler drums. The superheater coils usually are located in the path of the hot gases from the boiler furnace from which the coils absorb a portion of the waste heat as it passes off to the stack. The earliest recorded attempt to use superheated steam in a steam engine is that of Richard Trevethick, an Englishman, who, in 1832, used superheated steam in a condensing pumping engine making eight revolutions per minute and having a boiler pressure of 45 pounds per square inch.

Why Superheated Steam is Used. — The greatest thermodynamic loss in the steam engine — with the exception of the heat lost in the exhaust, which may be partially recovered, because exhaust steam can be used for such purposes as heating buildings and feed water — is the loss of heat due to initial condensation and reëvaporation in the cylinder. In the ordinary steam engine, this loss will amount to as much as 20 per cent of the entire steam fed to the cylinder. The explanation of this great loss is as follows: The steam which enters the cylinder of an engine comes in contact with cylinder walls which are at a temperature lower than that of the entering steam, owing to the fact that steam at the lower temperature of the exhaust has just left the cylinder. Instantly, therefore, a thin film of steam is condensed upon the cylinder walls, thus decreasing the volume of the steam admitted, so that the total weight fed to the cylinder per stroke is in excess

of that which would have been fed had there been no condensation. Later, during expansion, when the energy of the steam is being converted into useful work, and its temperature has fallen, part of the steam which originally condensed on the cylinder walls is reëvaporated because the temperature of the steam has fallen below that of the cylinder walls, causing a natural flow of heat from the cylinder walls to the body of the steam. The heat necessary to accomplish this reëvaporation is wasted, because it does no useful work. The varying difference in temperature between the steam and the cylinder walls, therefore, causes a double loss in initial condensation and in the subsequent reëvaporation. The amount of initial condensation can be figured by noting the difference between the actual amount of steam used per stroke, as shown by the amount of boiler feed water, or the condensate from the cylinder, and the amount per stroke accounted for by the indicator card at cut-off. By comparing the amount of steam in the cylinder, at the point of cut-off, as accounted for by the indicator card, with the amount in the cylinder at the point of release, as accounted for by the indicator card, it is possible to form an idea of the amount of steam which has been reëvaporated during the stroke.

Now, if superheated steam be used in the cylinder instead of wet or saturated steam, loss of heat will lower the temperature of the steam without condensing it, if the degree of superheat be high enough, as no condensation of steam can occur until all of the superheat is removed. Subsequently, then, there will be no reëvaporation of moist steam, as no moisture has been formed. Moreover, the change in the original volume of the steam due to decreasing the degree of superheat is negligible compared with that caused by condensation, so that the weight of steam is not appreciably affected thereby; also, the difference in temperature of the cylinder walls has less effect, as superheated steam is a very poor conductor of heat compared with saturated or wet steam.

SUPERHEATERS FOR STEAM. Superheaters are of two general types: Those that are placed in the boiler setting in some one of the passes where they are exposed to the hot gases on the way to the stack, and those that are constructed with a separate and independently fired furnace. Internal superheaters are adaptations to existing standard boilers and furnaces, and may be easily installed in existing plants, although equally adaptable to new ones. Independently fired superheaters require the construction of a new furnace and grate. In both types of superheaters, a coil of wrought iron or steel pipe is exposed to the hot furnace gases. Through this coil of pipe the steam flows on its way from the superheater to the engine or turbine.

SUPER-POWER. The term " super-power " relates to developments tending toward economical methods of generating and distributing power.

An increasing number of water power plants and steam plants of large sizes are being developed and because of certain economic advantages, with which all engineers are familiar, the tendency is to connect groups of power plants together, forming large composite systems. By its very nature a composite system can produce power at a lower cost than an isolated local company. It is assumed, therefore, that the growth of these composite systems will continue until eventually a few "super-power" systems, drawing upon all economical sources of power within the area they cover, will supply electric energy to large territories. Local companies, by joining the super-power systems, are able to turn their surplus power into the common reservoir for general use and can draw from the same reservoir such additional power as they may require in emergencies.

SUPPLEMENT OF ANGLE. The supplement of a given angle (a) equals $180° - a$; hence, if angle a exceeds 180 degrees, the supplement is negative. The supplement angle of a 120-degree angle equals $180 - 120 = 60$ degrees.

SURFACE COMBUSTION. If a mixture of gas and air, which is being emitted at a high velocity from a Bunsen burner, is permitted to strike against a piece of red-hot firebrick held a short distance away from the front of the burner, the mixture will burn at the surface of the firebrick. This constitutes the principle from which the methods of what is called *surface combustion* have been developed. In the practical application of surface combustion, an explosive mixture of gas and air in the proper proportions for complete combustion, or with air in slight excess, is caused to burn without flame in contact with a granular incandescent solid, whereby a large proportion of the potential energy of the gas is immediately converted into radiant form. The principle is the same as having a multitude of small burners instead of one or a few large burners. The advantages claimed for the system are that the combustion is greatly accelerated by the incandescent surface, and can be concentrated just where the heat is required; the combustion is perfect with a minimum excess of air; the attainment of very high temperatures is possible; and owing to the large amount of radiant energy developed, the transmission of heat to the object to be heated is very rapid. Boilers arranged for surface combustion have a mixing chamber in front of the tubes and connecting with them. The tubes contain the granular refractory material. The gas mixture is forced through the tubes at a high velocity, and complete combustion is insured after the gas has traversed a very short distance. The remainder of the granular material in the tubes acts as a baffle for the hot gases, forcing them toward the walls of the tubes in order that a large proportion of the heat may be given over to the water. Surface combustion fires can be run efficiently at temperatures in excess of

3000 degrees F. It is possible to consume efficiently a volume of gas equivalent in heating power to 150 pounds of coal per hour per square foot of fuel bed while not more than from 60 to 70 pounds per square foot of grate area can be burned on locomotive boiler grates. This intensity of fuel consumption coupled with almost perfect combustion produces an intensely hot radiant fire. There being no excess of air, a minimum of heat is carried off in the waste gases.

SURFACE CONDENSER. In this type of condenser for condensing exhaust steam from engines or turbines, the condensing water and the steam are kept separate, the condensation being effected by the contact of the steam with metallic surfaces cooled by the continuous circulation of the water. A surface condenser consists mainly of a condensing chamber containing horizontal tubes connecting with small chambers at each end, separated from the main chamber by heads or tube sheets. The exhaust steam from the engine or turbine enters the condensing chamber, while the cooling water, forced by a circulating pump, passes through the tubes.

SURFACE GAGE. The surface gage is used extensively for scribing lines that represent finished surfaces, and also for testing the parallelism between a surface and the table of a machine, such as the planer or shaper. A common form of surface gage has rather a heavy base on which is mounted a rod carrying a pointer or scriber. The latter can be adjusted in or out, and it can also be moved to any position along the rod.

SURFACE GRINDING MACHINES. The grinding of plane or flat surfaces is known as surface grinding, and there are several different types of machines used for this work. The surface grinder is indispensable in the tool-room for truing parts that have been distorted by hardening and for producing fine accurate surfaces. Many of the surface grinding machines built at the present time are also efficient for producing flat surfaces in connection with manufacturing operations. Ordinarily, the surface grinder is used for finishing parts which have been milled or planed approximately to size, although many pieces are ground from the rough on the large machines used for manufacturing purposes. Surface grinders vary both in regard to the form of the grinding wheels used and the movement imparted to the work-table when grinding. For instance, the work-tables on some machines operate with a reciprocating motion, whereas others rotate; the grinding is done on some machines with a disk-shaped wheel, whereas other machines have a cup- or ring-wheel. Some of these grinders are comparatively small in size and light in construction and are designed more particularly for tool-room use, whereas others are large and powerful, and are employed for grinding duplicate parts in connection with manufacturing operations.

Horizontal Face Grinding Machines. — Surface grinding machines of the

horizontal face-grinding type have a grinding wheel of the ring or cylinder form, the face or edge of which is used for grinding; hence, the name " edge grinder " is applied to machines of this class by some manufacturers. The face grinder is preferable for certain classes of work to the type of machine using a wheel that grinds on the periphery. The horizontal face grinder, which has a horizontal wheel spindle, and work-table, is especially adapted to that class of work which can be held to better advantage when the surface to be finished is in a vertical plane as the edge of the ring wheel is vertical. For example, the ends of rather long castings, such as machine legs, etc., can easily be ground on this style of grinder, because the work can readily be clamped to the table of the machine in a horizontal position. The horizontal face grinder is used in locomotive shops for truing or finishing the bearing surfaces of guide-bars and can be employed to advantage for many other grinding operations.

Vertical-spindle Surface Grinders. — Many vertical-spindle surface grinding machines are in use which have a cup- or ring-wheel and a rectangular work-table that has a reciprocating motion when the machine is in operation and grinding rectangular surfaces or parts that should move in a straight line beneath the wheel. The length of the table stroke is controlled by dogs in the usual manner. Rotary attachments or circular work-tables are often supplied with such machines so that the sides of saws, rings, or flat disk-shaped parts may be rotated while being ground by placing them on the rotary table or chuck which is mounted on the grinder table, the table remaining stationary. This type of grinder can be used advantageously for grinding long rectangular surfaces or disk-shaped parts (by using the circular attachment), and it is very efficient for grinding a number of small castings simultaneously.

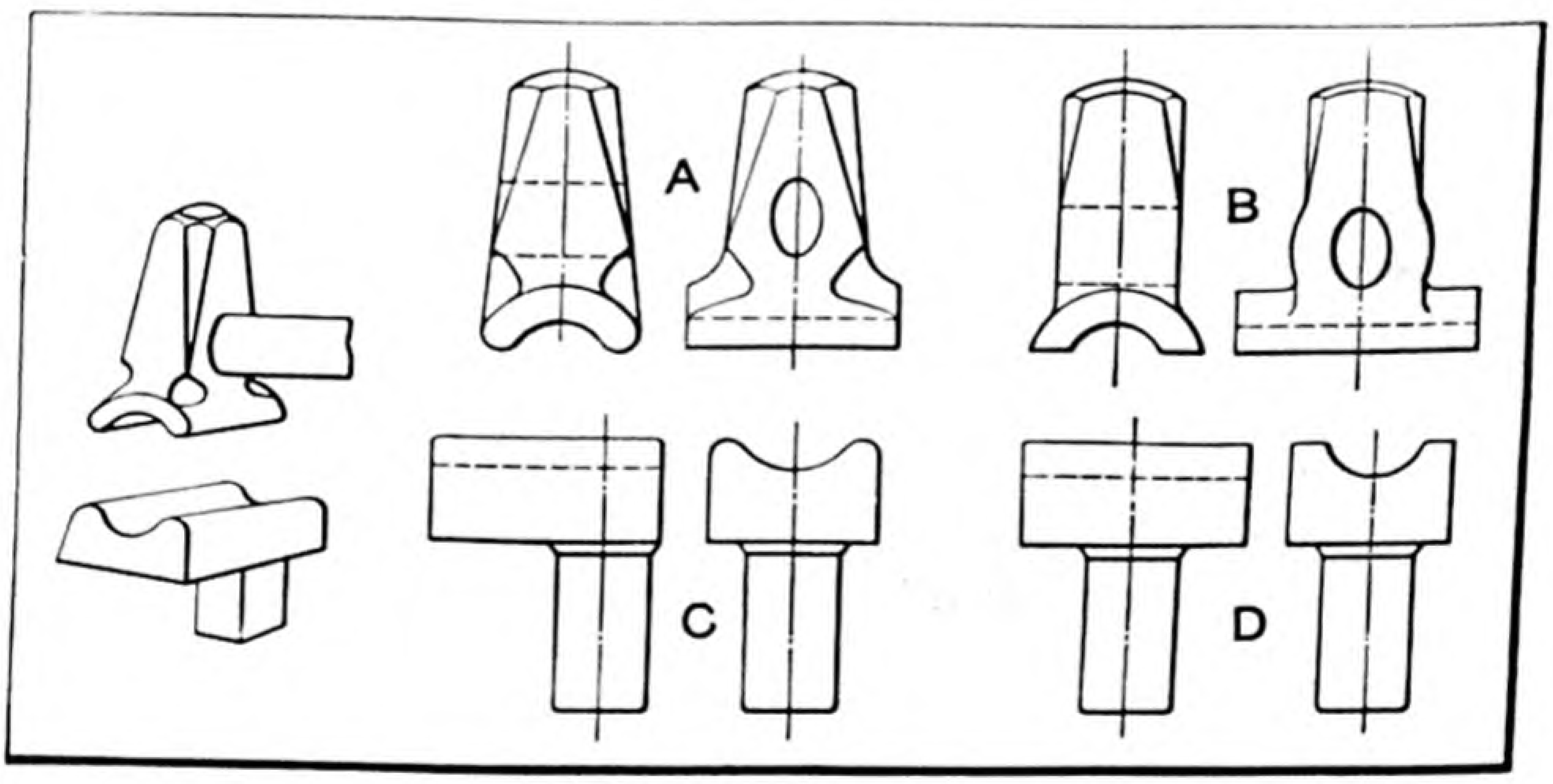
Some vertical-spindle surface grinders have a rotary work-table. One of these larger designs, which is intended for grinding duplicate parts in connection with manufacturing operations, has a rotary work-table which is mounted on a slide that enables the table to be withdrawn from under the wheel, and in a position convenient for loading with new parts to be ground.

SURFACE PLATE. Surface plates have plane or flat surfaces and are used in machine construction for testing flat surfaces and other parts and also as a base-plate from which to measure in laying out work. Usually they are made of hard close-grained cast iron, either square or rectangular in shape, and vary in size from a few inches to several feet in length and width. The method of originating straightedges by fitting three together until any two are a perfect fit (as near as can be determined by a practical test) can also be applied to the making of surface plates. Obviously, if only two plates are put together, they may not have true plane surfaces, even though they show a good bearing when tested. This is be-

cause the inaccuracy in one place will often be concealed by corresponding inaccuracies in the other. Therefore, to secure accurate results, three plates should be scraped in together, these being numbered 1, 2, and 3. First, fit Nos. 3 and 2 to No. 1. When this has been done, Nos. 2 and 3 are, practically speaking, duplicates. The second step is to fit Nos. 2 and 3 together by scraping about as much from one plate as from the other in order to reduce any error which may have been copied from No. 1; third, fit No. 1 to No. 2; fourth, fit No. 3 to No. 1; fifth, fit No. 2 to No. 3 by scraping as much from one plate as the other. Continue this series of operations carefully until plate No. 1 will fit Nos. 2 and 3, and No. 2 will fit Nos. 1 and 3. Having originated three plates in this way, one can be laid aside to be used as a master plate for testing the others which are employed in active service.

SURVEYOR'S MEASURE. 1 mile = 8 furlongs = 80 chains; 1 furlong = 10 chains = 220 yards; 1 chain = 4 rods = 22 yards = 66 feet = 100 links; 1 link = 7.92 inches.

SWAGE. The term *swage* applies to a number of different kinds of tools with hollow impressions in their faces, but the most common kind is for finishing plain round work. Swages are made in pairs, top and bottom to



Swages used in Hand Forging

match. The depth of the impression ought to be about one-third the diameter of the piece the swages are intended to finish. In the accompanying illustration *A* represents the correct style of top swage, and *B* an objectionable style; *C* shows the correct style of bottom swage, and *D* the incorrect style.

SWAGING. Cold swaging is a method of reducing or forming steel or other material, while cold, by means of a machine that caused the work to be struck a large number of successive blows by a pair of dies or hammers.

This process is applied principally to the reduction of wires, rods, and tubes, either for tapering or pointing the ends or reducing the diameter in one or more places, and it is the only method by which rolled or plated stock can be reduced without destroying the plating or coating. For this reason, swaging is largely employed in connection with the manufacture of jewelry, spectacle parts, fancy pins, etc. The method is also extensively used for pointing rods or tubes which are to be drawn. The millions of needles, bicycle spokes, button-hooks, crochet needles, and similar articles which are produced annually indicate some of the possibilities of the swaging process. The rotary swaging machine having dies mounted in the revolving head, is the type commonly used, although the horizontal design having dies which operate in a horizontal direction is used for some purposes.

SWAGING BY HOT PROCESS. The hot-swaging of metal has been found especially economical in the making of carbon steel drills and end-mills and for the manufacture of motorcycle pedal pins, spinning spindles used in the cotton industry and similar parts. The rolls that impart a radial movement to the dies of a cold-swaging machine are carried by a cage having a floating or slow rotary movement. This construction causes a sliding blow to be delivered to the work, which is suitable for the cold-swaging process, but not for hot-swaging. One design of hot-swaging machine head is so arranged that the rolls rotate on their axes while held in a fixed position; as a result the blows are delivered directly and quickly to the work without producing any torsional effect. The severe service imposed upon a machine by the swaging of hot metal demands a heavily constructed machine and means for keeping the dies cool. In one type of machine this is accomplished by placing a water jacket around the head roll bearing.

SWAGING DIES. Swaging dies for use in power presses, are a type in which parts are formed to the required shape by compressing the metal so that the impressions in the punch and die-faces are reproduced upon the work; in other words, instead of shaping the metal by cutting, bending, or drawing, it is formed by compression. The pressure required for swaging is relatively high because it must be sufficient to cause the metal to flow into the punch and die-cavities or depressions.

SWEATING. When parts are soldered together by heating them sufficiently to melt the solder, instead of using a soldering iron, the operation is often known as *sweating*. Brass boxes for engine connecting-rods are sometimes sweated together prior to machining, in order to hold the two halves in alignment while finishing the sides and boring. The finished surfaces forming the joint between the brasses are first tinned or covered with solder. This is done by heating the brasses enough to melt the solder, then applying a flux (such as sal-ammoniac), and finally the solder. After

tinning, the brasses are again heated if the solder has hardened; they are then put together and allowed to cool. The halves are separated after machining by heating them until the solder melts, after which the sweated surfaces are cleaned off.

SWING CRANE. The name swing crane is applied to pillar cranes that have a rotary motion only, but which are not provided with a trolley on a horizontal arm. The name is also applied to jib cranes if they are not provided with a trolley.

SWING-FRAME GRINDING MACHINES. The swing-frame grinding machine was designed for the purpose of removing the fins, gates, and wires left by and in molding, from castings too heavy to be conveniently lifted by hand. One wheel only is mounted on a machine, and the arm on which the wheel is mounted has a large radius of swing and is designed, in some cases, to travel laterally on a track. Swing-frame machines are the heavy-duty machines in the foundry and are rigidly constructed. Great pressure of the wheel on the work is possible, because at times the operator bears his whole weight on the handles of the machine.

SWISS SCREW THREAD. This is a thread system originated in Switzerland as a standard for screws used in watch and clock making. The angle between the two sides of the thread is 47 degrees 30 minutes, and the top and bottom of the thread are rounded. This system has been adopted by the British Association as a standard for small screws, and is known as the British Association thread.

SWITCHBOARD. A switchboard consists of instruments, meters, and controlling devices necessary for the proper protection and measuring of electrical circuits, assembled in a convenient and symmetrical manner on an insulating and supporting structure. The switchboard furnishes the connecting link between the generation and distribution of electrical power, and is sometimes referred to as the nerve center of an electrical system.

SWITCHBOARD MATERIALS. The materials from which switchboard panels are made must be fireproof, have insulating properties, be strong mechanically, and, for the average installation, must be reasonable in price. The two materials in general use are slate and marble. Slate is used to a much greater extent than any other material for switchboards. It must be carefully selected for insulating qualities and mechanical strength. When used in its natural color, consideration is also given to appearance. The four varieties of slate furnished for switchboard use are: (1) Natural black slate. (2) Dull black marine finished slate. (3) Black enameled slate. (4) Marbleized slate. Owing to its greater strength as compared with marble, slate is recommended for switchboard use when the potential used directly

on the panel does not exceed 1200 volts for natural black slate and 650 volts for dull black marine finished slate. Marble is suitable when the potential directly on the panel does not exceed 3300 volts, and should be used in all cases when the potential on the apparatus mounted directly on the panel without insulating bushings exceeds 1200 volts. There are several varieties of marble suitable for switchboard work, the most serviceable being blue Vermont marble. Pink and gray Tennessee, white Italian, and white Vermont marbles are used to a less extent.

SWITCH CONTROLLER. This is a hand-operated electric motor controller of the non-automatic type made in two designs, one known as the "single-switch type" and the other as the "multiple-switch type." The single-switch type is used in starting squirrel-cage motors up to about 5 horsepower in size, although it has sometimes been applied to motors as large as 25 horsepower, and may be either single- or double-throw, usually having the contacts oil-immersed. The multiple-switch type is built to handle heavy currents and may be applied to motors from 50 to 75 horsepower and larger. It is mechanically strong, has a long life, but is more expensive than most other types of controllers, occupies more space, and is difficult to operate rapidly.

SWITCHES. See Brush Switches; Control Switches; Disconnecting Switches; Starting Switches.

SWITCHES, AIR-BREAK TYPE. An air-break switch has contacts which make and break contact in the air as contrasted with an oil switch in which the contacts make and break under oil. The air-break switch may be enclosed by some form of cover for the purpose of protecting the operator or to prevent unauthorized operation. Air-break switches can be used up to any voltage or current commercially feasible. The construction varies according to requirements. There are several kinds, such as lever, brush, rotary, plug, and push-and-pull switches.

SWITCHES, OIL TYPE. An oil switch is a device for closing and opening an electrical circuit by the movement of contact parts which make and break contact while submerged in oil. Some manufacturers apply the term "oil switch" when the device is used only to open an unloaded circuit or a loaded circuit, at the will of the operator; and the term "oil circuit-breaker" is used when the switch is utilized to break the circuit automatically under abnormal conditions. This distinction, although considered correct by the American Institute of Electrical Engineers, is not universally accepted. Oil switches are used almost invariably on alternating-current systems. They are used on low-voltage circuits when air-break switches are objectionable, either because of head-room, limited space for connections, or where

the open arc is a source of danger; and on high-voltage circuits, where air-break devices are not practicable, owing to the space required for breaking a high-voltage arc in air. The fact that the oil switch breaks the arc under oil makes it especially valuable for service in plants where inflammable or explosive dust or gases are prevalent; in cotton mills, where lint or oil would make an air-break switch objectionable; in powder mills, chemical factories, or gaseous mines; or under any conditions in which an air arc might cause a short-circuit or a ground of some adjacent circuit. Oil switches are particularly effective on alternating-current circuits, because, as the switch contacts separate, the oil surrounding the contacts immediately rushes to fill the space in the break between the contacts, and introduces a high resistance which is in proportion to the speed at which the contacts part. Also, the pressure of the oil confines the arc to a limited area and tends to quench it. When the voltage passes through zero, the resistance of the oil tends to prevent the arc from reëstablishing. The oil switch is not nearly so effective on direct current. As there is no zero potential point in this case, the breaking of a direct-current circuit under oil results in severe burning of the metal and oil, and the generation of much gas; consequently, there is considerable tendency of the arc to hold between the opening contacts. However, oil switches are sometimes used on direct-current circuits where conditions are such that, to break an arc in the open air, is prohibitive. There are several factors to be considered in selecting oil for use in an oil switch; namely, flash point, burning point, viscosity, and cold test. The flash and burning points must be high. The oil used should be obtained from the oil switch manufacturer or ordered from specifications furnished by him.

SWIVEL BASE. The lower part of a chuck, vise, slide, or other machine part is called a swivel base when it is so arranged that it can be turned or rotated about a center, so that the chuck, vise, etc., attached to it may be turned to any angle. The swivel base is generally graduated to show the angle.

SYMBOLS, MATHEMATICAL. See Mathematical Symbols.

SYNCHRONISM INDICATORS. The synchronism indicator affords a quick and safe means for paralleling alternating-current machines, as it shows when the machines are in phase and in step, indicating by the position of the pointer the difference in phase relations between the machines, and showing whether the incoming machine is running too fast or too slow. It is superior to synchronizing with lamps, because the latter give no indication of the relative speed of machines; the lamps will indicate when the machines are of the same frequency, but the phase relations can be judged only by the brilliancy of the lights.

SYNCHRONIZING RESISTANCE. A synchronizing resistance is used in connection with rotary converters for synchronizing purposes, when these are started by means of direct-connected induction motors. The starting motor raises the speed of the converter above synchronism, and, by connecting a resistance across one phase of the converter, it serves as a means of loading the machine to bring its speed down to synchronism.

SYNCHRONOUS CONDENSER. When a synchronous motor is operated idly, that is, without carrying any mechanical load, and simply supplies a wattless current for correcting the power factor of an installation, it is termed a *synchronous condenser*. It is used for power-factor correction and for maintaining constant voltage by power-factor control.

SYNCHRONOUS CONVERTERS. The synchronous converter is a rotating machine for converting alternating current into direct current or *vice versa*. In the former case, it is called a *synchronous converter;* in the latter, an *inverted synchronous converter*. The term *rotary converter* is also frequently used. While a motor-generator set requires two machines, as the name implies, the synchronous converter consists of only one machine.

In general, the construction of a synchronous converter is similar to that of a direct-current generator with the addition of collector rings connected to the armature winding at equal distances around the armature. It differs, however, in several important details, notably in the shape of the pole tips and the addition of heavy copper dampers in the pole faces to prevent unstable operation and to assist in starting from the alternating-current side. No transfer of mechanical energy takes place in synchronous converters, because the torque consumed by the generation of the direct current and the torque produced by the alternating current are applied at the same conductors. As a result, the mechanical parts of a synchronous converter can be made much smaller than the corresponding parts of a direct-current generator.

Synchronous converters are built in single-, two-, three-, and six-phase, but, owing to the very general use of three-phase transmission, only the two last types are, as a rule, standardized. More than 90 per cent of the alternating-current systems in the United States are of either 25- or 60-cycle frequency; these frequencies, therefore, have been adopted as standard for synchronous converters. The 25-cycle is mainly used for power and railway work, and the 60-cycle, for lighting service.

SYNCHRONOUS GENERATOR. See Generators, Alternating-current.

SYNCHRONOUS MOTORS. The synchronous motor is essentially a synchronous generator with reversed rotation, and, in general, any alternator will operate as a synchronous motor or *vice versa*. There are, however,

certain features wherein the motor differs from an alternator, as in the addition of a starting winding, etc. The stator of a synchronous motor is constructed in exactly the same way as that of a synchronous generator. It is commonly called the *armature*. The rotor of the synchronous motor is called its *field*; it consists of a *field spider* which is mounted on the shaft the same as the rotor spider of an induction motor, but which carries *field poles* instead of laminations with slots and windings. The poles are usually of laminated sheet steel, the individual sheets usually being several times thicker than those of the armature punchings.

SYNCHROSCOPE. A synchroscope, or synchronism indicator, is a device which, besides showing when two alternating-current systems are in synchronism, also indicates which system has the higher frequency, the difference in frequencies, and the phase relation when the frequencies are equal. They are commonly of the dynamometer or the moving-iron types, being similar in their operation to power-factor meters in that their indications are dependent upon the phase difference between two currents.

SYNTHETIC CHEMISTRY. Synthetic chemistry is that part of chemistry which deals with the building-up of more complicated from less complicated substances. The term " synthetic " is also used for substances made by artificial means in the laboratory to distinguish them from like substances obtained direct from plants and animals.

SYNTHETIC REACTION. Synthetic reaction is a chemical reaction in which two or more elements or compounds unite to form a single product.

TACHAGRAPH. The tachagraph is a tachometer of a very sensitive type. It is used to measure minute changes of speed within a single revolution and produce an autographic diagram of the angular velocity.

TACHOMETER. Tachometers are made in different types for indicating the speed in revolutions per minute of rotating shafts, the peripheral speeds of flywheels or pulleys, the lineal speed of belts or hoisting ropes, and various other speed measurements. Tachometers may have a dial graduated to represent revolutions per minute and an indicating hand which gives the direct reading, or the instrument may make a permanent record of the speed by drawing a line upon a graduated chart. Some of these recording tachometers or tachographs have a dial in addition to the recording chart. Precision instruments are also made for testing the angular variations of flywheels, variations in the speed of machines due to slipping of belts, or any irregularity in running. An *electric tachometer* of the type generally used may have the indicating or recording instrument located at any distant point from the shaft, the speed of which is to be recorded.

TAILSTOCK. A tailstock is that part of a machine tool, such as an engine lathe or cylindrical grinding machine, which is used to support upon a conical center the outer end of a rod, shaft, or other piece which is being turned or ground. The body forming the tailstock may be clamped in different positions along the machine bed for accommodating work of different lengths, and the tailstock spindle containing the supporting center is adjustable to allow for small variations in length. The upper part of a lathe tailstock body is adjustable in a lateral direction so that the axis of the work may be inclined relative to the movement of the tool carriage, in order to turn tapering parts when the lathe is without a taper attachment.

In bench lathe practice, the tailstock is frequently used as a means of holding and feeding various classes of tools. Tailstocks for bench lathes are made in several different forms. The type intended primarily for supporting one end of centered work is designed along the general lines of the engine lathe tailstock. Then there is a lever-operated tailstock for drilling, reaming, counterboring, and similar operations. Another form is operated through a rack and pinion in conjunction with a hand-lever. The cross-slide adjustment provided in this case is useful for recessing, facing, and counterboring. The "half-open" tailstock is employed for light operations such as drilling, reaming, lapping, and the cutting of very small threads with taps or dies, while the revolving-spindle tailstock is applied to certain drilling operations. The "sliding" or "open" tailstock is similar to the half-open design, except that it has full or complete bearings. The spindle has a knob at one end and is moved by hand the same as the spindle of a traverse grinder.

TALC. Talc is a mineral known as steatite or soapstone. Chemically, it consists of magnesium silicate ($H_2 Mg_3 Si_4 O_{12}$). Steatite or soapstone is usually a white or gray substance. The specific gravity varies from 2.6 to 2.8. Its extreme softness and the fact that the surface feels greasy make it easily recognized. Talc has been experimented with as a lubricant similar to graphite. It is, however, not acted upon by tannin solutions, like graphite, but it may be brought into a fine molecular state by heating with ammonium carbonate or by exposing it for several hours to a current of dry ammonia. The talc is afterward dried in a vacuum. The treated material can be suspended in water, so that it is very difficult to filter it, and subsides exceedingly slow in lubricating oils of medium density. When once suspended in a neutral oil, the talc does not subside on heating. The change in the character of the talc is attributed to the absorption of a minute quantity of ammonia. From 40 to 60 per cent of ordinary talc may be introduced into heavy mineral oil, provided the oil be added to the talc and the operation not carried on in the reverse manner.

TAN. This is a Chinese capacity measure, legalized in 1908. It is equal to 103.55 liters or 27.36 gallons.

TANDEM-COMPOUND ENGINES. The engine known as the tandem-compound is so designed that the high-pressure cylinder and the low-pressure cylinder are in line. There is only one piston-rod, the high- and low-pressure pistons being mounted on the same rod. The general appearance of an engine of this design is the same as that of a simple engine, except for the addition of the high-pressure cylinder.

TANDEM DIES. See Follow Dies.

TANGENT, ARC. See Arc Sine and Tangent.

TANGENTIAL LOAD. A load applied to a circular body, such as a gear or pulley, in the direction of a tangent to its circumference, is known as a tangential load. To find the tangential load at the pitch-line of spur gearing, multiply 33,000 by the number of horsepower being transmitted, and divide the product by the pitch-line velocity in feet per minute.

TANGENT OF ANGLE. See Functions of Angles.

TANG OF DRILL SHANK. See Drill Shanks in paragraph on Drills.

TANTALUM. Tantalum is a metal of silver-white color, highly ductile, and remarkably hard, if hammered. The tensile strength of tantalum is higher than that of steel, but it is so sparingly distributed in nature that it is of comparatively little importance. It has been used to some extent in metallic filament lamps, but tungsten is now used almost exclusively for this purpose. Tantalum has a specific gravity of 16.64. It melts at a

temperature of 2850 degrees C. (about 5160 degrees F.). Its specific heat is 0.0365, and its coefficient of linear expansion per unit length, per degree F., 0.0000045. Tantalum belongs to the same group of metals as vanadium and columbium. If it occurred in nature more freely, it would probably be a metal of considerable importance.

TAP BOLT. A tap bolt is used without a nut, the threaded end being screwed into a tapped hole in one of the parts to be held by the bolt; hence, the name, tap bolt. Tap bolts and cap-screws are used in the same way, but they differ in regard to the sizes of the heads. Tap bolt heads are made to the same sizes as ordinary bolt heads, whereas cap-screw heads are somewhat smaller and thicker. There is no universal standard, however, at the present time, either for bolt heads or cap-screw heads, although most of the bolts manufactured have heads of corresponding sizes, which is also true of cap-screws.

TAP DRILL DIAMETERS. Tapping troubles are often caused by using tap drills that are too small in diameter. For ordinary manufacturing, not more than 75 or 80 per cent of the standard thread depth is necessary, and for some classes of work not more than 50 per cent is required. Tap drill sizes, especially for machine screws, should be varied according to the material to be tapped and the depth of the tapped hole. The diameters of tap drills can be found by the formula $D = T - 0.75 \times 2d$, in which D = drill diameter; T = diameter of tap or thread; d = depth of thread. The diameters obtained by this formula allow for a thread having 75 per cent of the standard depth which is sufficient for general work. The full depth of a United States standard thread equals 0.6495 times the pitch of the thread, and the full depth of a sharp V-thread equals 0.866 times the pitch.

TAPER. See Brown & Sharpe Taper; Jarno Taper; Morse Taper.

TAPER ATTACHMENT, ENGINE LATHE. Turning tapers by setting over the tailstock center has some objectionable features. When the lathe centers are not in alignment, as when set for taper turning, they bear unevenly in the work centers, because the axis of the work is at an angle with them; this causes the work centers to wear unevenly and results in inaccuracy. Furthermore, the adjustment of the tailstock center must be changed for turning duplicate tapers, unless the length of each piece and the depth of the center holes are the same. If the tailstock center is offset for taper threading a "drunken thread" or one which does not follow a true helix, will result, owing to an irregular turning movement. To overcome these objections, many modern lathes are equipped with a special device for turning tapers, known as a *taper attachment*, which permits the lathe centers to be kept in alignment for taper work the same as for cylindrical turning, and enables more accurate work to be done.

TAPER PINS. Taper pins are used as a means for securing two parts of a machine or device to each other; the most common application is for securing collars or hubs to shafts. There is a generally accepted standard for these pins. The taper is $\frac{1}{4}$ inch per foot. The pins of different sizes are known by numbers. The diameters at the large end vary from 0.094 inch for pin No. 00000 to 1.523 inch for pin No. 14.

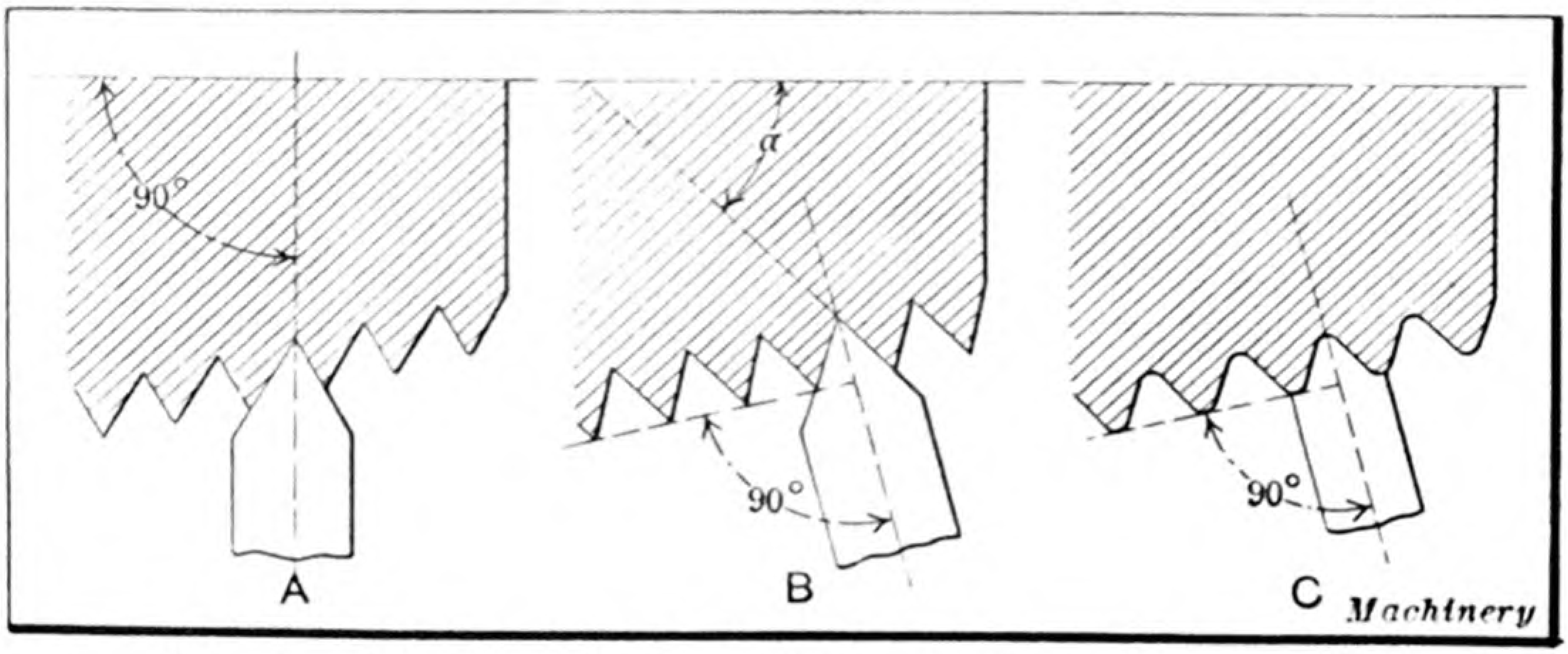
TAPERS FOR MACHINE SPINDLES. In general practice, it is customary to use Morse tapers for drilling machines, but for grinding machines and lathes, the practice varies considerably. Of ten large grinding machine manufacturers three use Brown & Sharpe tapers for the centers, three use Morse, and four use Jarno. In the case of lathes, out of thirty-three large concerns, twenty use Morse, one Brown & Sharpe, five Jarno, two Reed (which is a short Jarno), two modified Morse (longer than the standard Morse but the same taper), and three use tapers entirely of their own design. The spindles of practically all milling machines in use at the present time have the Brown & Sharpe taper and this same taper is also used for dividing head spindles. The standard milling machine spindle adopted in 1927 by the milling machine manufacturers of the National Machine Tool Builders' Association, has a taper of $3\frac{1}{2}$ inches per foot. This comparatively steep taper has been adopted to insure instant release of arbors.

In the Morse taper system there are six different tapers per foot, every taper except Nos. 2 and 3 being different. The Brown & Sharpe tapers are all one-half inch per foot, except No. 10, which is 0.5161 inch per foot. With the Brown & Sharpe tapers there are more than two lengths of shanks for the same number in many instances.

TAPER THREAD CUTTING. It is the general practice in the United States to set a tool for cutting tapered screw threads as shown at *A*, or so that the sides of the thread incline equally with reference to a line perpendicular to the axis of the screw. The principal reason why taper threads should be cut with the tool in this position is that taper taps are made in this way or with the threads normal to the axis. If the tool were set in the position shown at *B* or so that the sides of the thread incline equally with reference to the tapering surface, obviously such a thread would be a poor fit in a hole tapped with an ordinary taper tap having threads normal to the axis as at *A*. If the hole and the tapering part which screws into it were both threaded normal to the surface as at *B*, the thread would be satisfactory unless there were an unusual amount of taper. In extreme cases, angle α (see diagram *B*) of one side of the thread might be so small that the radial or bursting pressure on the nut would be excessive owing to the wedging action.

It is the practice to cut Whitworth pipe threads and most other Whitworth

threads which are tapering with a tool set perpendicular to the side of the tapering surface, as shown at *C*, because the same tools that are used for parallel threads can then be used for taper threads. If a tool used for parallel thread cutting were set at right angles to the axis, one side of the crest of the thread would not be cut to a circular form if the tool were of the shape illustrated, because the curved cutting edges would be the same distance from the axis of the screw and only one side of the circular part of the tool would cut. This difficulty is not encountered with the thread forms like the U. S. standard or V-threads.



Correct and Incorrect Positions of Tool for Taper Thread Cutting

The top cutting face of the tool should lie in a horizontal plane coinciding with the axis of the work for all taper thread cutting. It is much more important to have the tool at the same height as the lathe centers when cutting taper threads than when cutting parallel threads for the reason that a section parallel to the axis of a cone is not straight but curved; consequently, not only is the angle of the thread changed but a curved tapering thread also is produced.

TAPES, METALLIC. Metallic measuring tapes are made by weaving thin brass wires into cloth to prevent the stretching of the tape. These are made in lengths of from 25 to 100 feet, but are not as accurate as steel tapes; in fact, metallic tapes, when subjected to rough handling and usage in alternating wet and dry weather, may stretch as much as a foot in one hundred feet. They are used only for measuring short distances, and in cases where accuracy is not important.

TAPES, STEEL. Owing to the wear and other disadvantages of measuring chains, they are gradually being displaced by heavy steel tapes. Steel tapes used by surveyors are made in lengths of 50, 100, 300, and 500 feet. The shorter tapes are graduated throughout their whole length into feet and tenths and hundredths of a foot. The heavier tapes are generally graduated

only at every foot, and only the last foot at each end is divided into tenths of a foot. Generally, the zero point is at the outer edge of the ring which is attached to the end of the tape, but some tapes are graduated so that the zero point is on the tape itself, from 2 to 3 inches from the end ring. The standard length of the tape is supposed to be obtained at a temperature of 62 degrees F., with a pull of twelve pounds on a tape supported throughout its length. The variations due to temperature and pull, however, are so small that they are not taken into account for any ordinary survey.

TAP EXTRACTOR. A tool for removing broken taps, consisting usually of projections or prongs spaced to engage the tap flutes, and with provision for turning, usually by means of a wrench applied to a square on the extractor. See also Taps, Removal of Broken.

TAP-HOLDER, FRICTION. Many tapped holes do not extend clear through the work, but are " blind;" hence, when the tap is driven by power, provision should be made for allowing the tap to stop in case it should strike the bottom of the hole, as otherwise it might be broken. Taps are also broken frequently, because the drilled holes are not large enough, the result being that the strain on the tap becomes excessive, and breakage occurs unless provision is made for limiting the amount of driving power. One method of safeguarding the tap is to hold it in a friction chuck or holder, which will slip in case the tap strikes the bottom of the hole or meets with excessive resistance to rotation. There are a number of different forms of friction tap- and drill-holders on the market. These differ as to the method of obtaining and varying the frictional resistance. On some drilling machines, an adjustable friction is introduced in the spindle-driving mechanism to prevent the breaking of taps.

TAPPER TAPS. The name " tapper tap," as understood by toolmakers and tap manufacturers, is applied to one of two kinds of taps used for tapping nuts in tapping machines. It is often confused with the expression " machine nut tap," which properly designates the second kind of taps used for this purpose. The machine nut tap, however, differs from the tapper tap in a number of particulars, the most important of which are the number and the form of the flutes, the relief of the threads, and the general design. The tapper tap is simpler in its details. Tapper taps, as a rule, are relieved only on the top of the thread of the chamfered portion. They are not relieved in the angle of the thread. The straight part, which performs no cutting, forming only the sizing part of the tap, should not be relieved, or, if relieved, the relief should be very slight in order to permit the tap to retain its size longer.

TAPPING ATTACHMENTS. Some drilling machines are equipped with special gearing which can be utilized for reversing the rotation of the spindle

when tapping, so that a special reversing tap chuck is not necessary. This mechanism for reversing the spindle when the tap has reached the required depth is often known as a tapping attachment.

TAPPING CHUCK OF REVERSING TYPE. In tapping by power, the tap ordinarily is fed down into the hole to the required depth and its rotation is then reversed for screwing it out of the hole. There are different methods of obtaining this reverse motion. When the tapping is done in an ordinary drilling machine, special tap chucks are frequently used, which are designed to reverse the rotation of the tap when the latter has reached the required depth. One form of tap-holding chuck is so arranged that the tap automatically stops when it strikes the bottom of the hole or when an adjustable depth gage comes against the top of the work. The raising of the spindle then reverses the tap which backs out at an increased speed.

TAPPING LUBRICANTS. Experiments have proved that the power required in tapping — that is, the resistance to the action of the tap when threading a nut — varies considerably with different lubricants. The following lubricants reduce the resistance to the cut when threading forged nuts, as well as those made from hexagon drawn material; the threads in the nut have a good finish and appearance: Stearine oil, lard oil, sperm oil, rape oil, and a mixture of 10 per cent graphite with 90 per cent tallow. A mixture of cutting emulsion with water also reduces the resistance to the threading action fairly well. In tests with emulsion, it was noted that it made very little difference how much water was mixed with the emulsion. A mixture of one part emulsion to 160 parts of water proved practically as good as a mixture of one part emulsion to ten parts of water.

Compound oils, that is, mineral oils mixed with animal or vegetable oils of the type usually employed for cooling lubricants for turning and milling, produce a considerably higher resistance than the animal or vegetable oils and cannot, therefore, be recommended for tapping. Mineral oils not mixed, and ordinary lubricating and machine oils, are wholly unsuitable. The resistance to cutting is very great, the taps break, and the threads in the nuts are badly torn; ordinary water reduces the cutting resistance better than some of the compound oils. Animal and vegetable oils, therefore, ought to be used exclusively for tapping.

Experiments on Lubricants for Tapping. — Experiments conducted at Gothenburg, Sweden, on a large scale, indicate that the generalizations made from the earlier experiments, as recorded in the foregoing, are correct. Animal and vegetable oils are the best for tapping mild steel, and of these stearine oil and " Winter-strained " lard oil are preferable. Mineral oils — machine oil — were found to be wholly unsuitable. Compound oils containing less than 50 per cent of animal or vegetable oil acted much the same

as the mineral oils and cannot be recommended for threading. When the compound oils contained over 50 per cent animal or vegetable oil, they could be used and were then found to be almost as good as the pure animal and vegetable oils.

A few emulsions have given almost as good results as animal and vegetable oils, but the kind of emulsion used plays an important part, and the majority of emulsions do not give good results. In almost all the tests made, a large volume of lubricant gave somewhat better results than a small quantity. This was particularly evident in the case of the thinner oils. Kerosene, turpentine, and graphite proved unsuitable for tapping steel.

With regard to the size of the hole tapped when different lubricants were used, it was found that the lubricant that produced the least resistance to tapping generally tended to produce the largest tapped hole. For example, when a hole was tapped dry, it would be a most accurate reproduction of the tap as far as size was concerned, but the threads were not clean and smooth, and, of course, the length of life of the tap was reduced. Water used as a lubricant produced good looking threads, but rather high resistance. Stearine oil, which reduced the resistance to tapping to the greatest extent, also produced the largest diameter in the hole.

For tapping aluminum, kerosene is recommended. For tapping cast iron use a strong solution of emulsion; oil has a tendency to make cast-iron chips clog in the flutes, thus preventing the lubricant from reaching the cutting teeth of the tap. For tapping copper, milk is a good lubricant.

TAPPING MACHINES. Machines designed especially for tapping or for drilling and tapping holes are made in quite a variety of designs. Some of these machines are intended for one class of work, like the tapping of nuts, whereas others are adapted to tapping operations of a general nature; there are vertical and horizontal, and single- and multiple-spindle types. Tapping machines also vary in regard to the mechanism for obtaining the forward and reverse motions of the tap spindle and the method of controlling these motions. A common arrangement for obtaining the two motions is by means of a clutch which is interposed between two pulleys revolving in opposite directions and is alternately engaged with these pulleys. The clutch may be controlled by (1) a hand-lever connecting with the clutch; (2) a foot-lever connecting with the clutch; (3) pushing the work and its fixture forward until contact is made with a stop-rod or lever which shifts the clutch for backing out the tap; (4) pushing the work against the tap while tapping and by pulling in the opposite direction for backing out the tap, the clutch being shifted by the direct thrust from the part being tapped and the resulting longitudinal motion of the tap spindles. The latter method is applied only to machines used for the lighter classes of work. The characteristic features of well-designed tapping machines are convenience of con-

trol and, for small tapping operations, a sensitive drive that will transmit enough power for operating the tap under normal conditions but not enough to break it in case the resistance to rotation becomes excessive.

Automatic Nut Tapper. — Various attempts have been made to design automatic machines for tapping nuts, that would operate continuously; many of these, however, have not proved satisfactory. One of these automatic machines which has proved efficient is equipped with a tap having a shank that is bent on a rather large radius so that the extreme end is at right angles to the main tap body. This shank with the right-angle bend is held in a groove in the spindle large enough to allow the nuts to slide over the shank. When the machine is in operation, the tapped nuts are forced along the shank around the curved end and ejected from an opening in the side of the spindle. The reason for using a bent tap is that the curved shank makes it possible to drive the tap and at the same time have it sufficiently free in the spindle opening to allow the nuts to pass over the shank and be ejected at the end; consequently, the machine can be operated continuously and without reversing the spindle or removing the tap for unloading the tapped nuts.

TAP RELIEF. See Relief of Taps.

TAPS. A tap is an internal thread-cutting tool having teeth which conform to the shape of the thread. Taps may be classified according to the kind of thread with which they are provided, as U. S. standard thread taps, square thread taps, and Acme thread taps, etc. The most important classification of taps, however, is according to their use.

Hand taps, as the name implies, are taps used for tapping holes by hand. All taps used in this manner, however, are not termed " hand " taps as there are many special taps used by hand which are known by specific names.

Tapper taps are used for tapping nuts in tapping machines. They are provided with a long chamfered part on the end of the threaded portion, and a long shank.

Machine nut taps are also used for tapping nuts in tapping machines. This type is designed for more severe duty than the tapper tap and is especially adapted for tapping holes in materials of tough structure. Machine nut taps are chamfered and relieved in a different manner from tapper taps.

Machine screw taps may be either hand taps or machine nut taps, but are known by the name " machine screw tap," because they constitute a class of special taps used for tapping holes for standard machine screw sizes.

Screw machine taps for tapping in the screw machine, are provided with shanks fitting either the turret holes of the machine or bushings inserted in these holes. As these taps ordinarily cut threads down to the bottom of the hole, they are provided with a very short chamfer.

Pulley taps are simply a special type of taps used for tapping holes which cannot be reached by ordinary hand taps, as, for instance, the set-screw or oil-cup holes in the hubs of pulleys. They are simply hand taps with a very long shank.

Die taps, also known as long taper die taps, are used for cutting the thread in a die in a single operation from the blank, and are intended to be followed by a sizing hob tap. Die taps are similar to machine nut taps.

Hob taps are used for sizing dies. They are intended only for the final finishing of the thread and can only take a slight chip. They are made to the same dimensions as regular hand taps, but fluted differently.

Sellers hobs are a special type of hob taps, differing from the ordinary hob in that they are provided with a long guide at the point of the thread. This guide or pilot is hardened and ground.

Pipe taps are used for tapping holes for standard pipe sizes. These taps are taper taps. There is also a special form of pipe tap termed *straight* pipe tap, which is simply a hand tap corresponding in diameter and number of threads per inch to standard pipe sizes.

Pipe hobs are similar to pipe taps, but are intended only for sizing pipe dies after the thread has been cut either by a pipe tap or in a lathe.

Boiler taps are used in steam boiler work where a steam-tight fit is required. They are made either straight or tapered. The straight boiler tap is practically only a hand tap.

Mud or *washout taps* are used in boiler or locomotive work. They are sometimes also called *arch pipe taps*. *Patch bolt taps* are used in boiler and locomotive work. These are taper taps similar to mud or washout taps.

Staybolt taps are used on locomotive boiler work. They are usually provided with a reamer portion preceding the threaded part, and have generally a long threaded portion and a long shank. A special form of staybolt tap is known as a *spindle staybolt tap* which revolves on a central spindle with a taper guide on the front end.

Stove-bolt taps and *carriage-bolt taps* are taps which have derived their names from the uses to which they were originally put. These taps have special forms of threads.

Bit-brace taps differ in no essential from the hand tap on the threaded portion, but are provided with a special shank for use in a bit brace.

Blacksmiths' taper taps are made for general rough threading and are used especially in repair work, where an accurately fitting thread is not required.

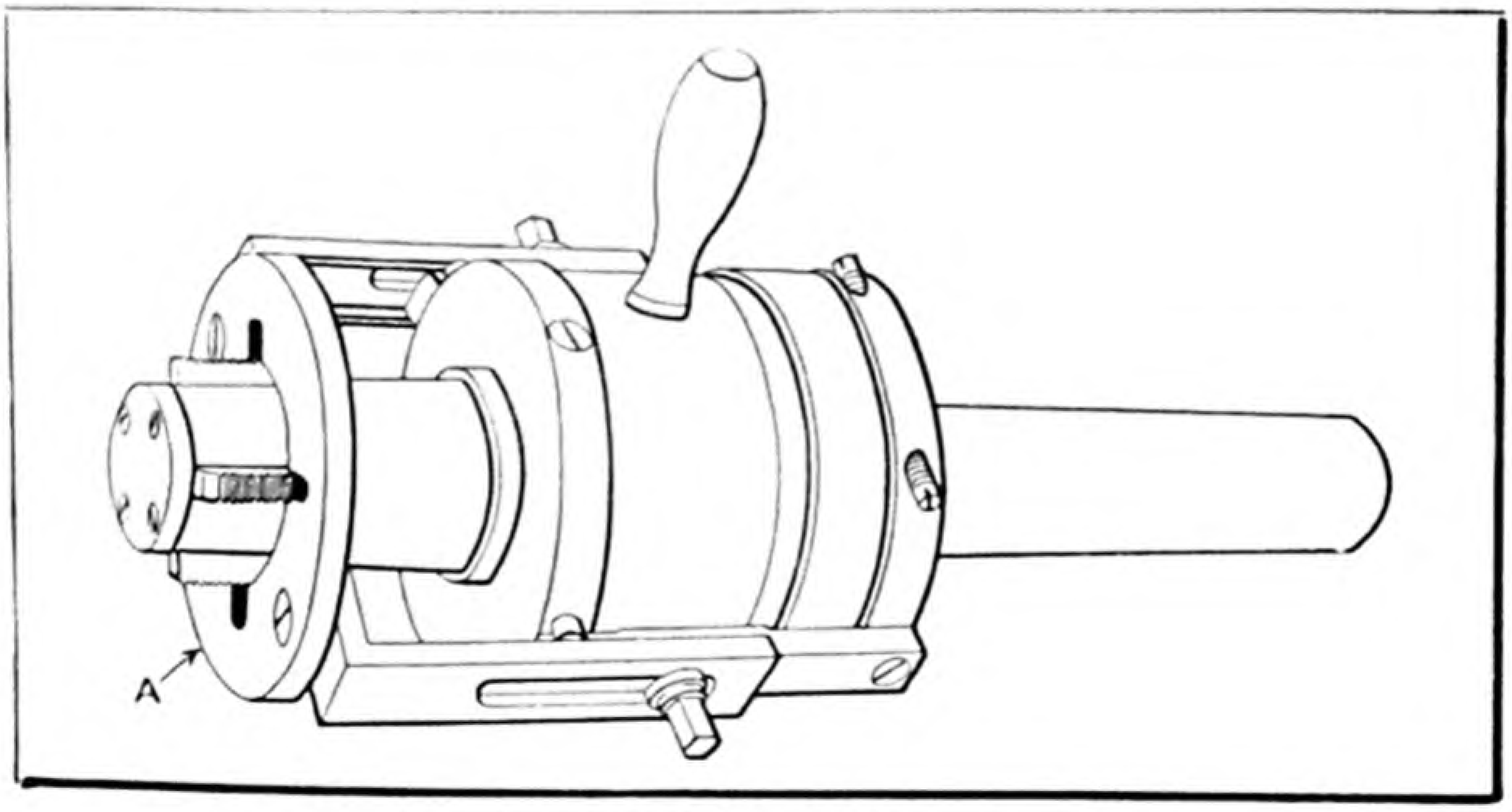
Inserted cutter taps may belong to any of the classes mentioned and constitute a separate type only because they are not solid, but have the cutting teeth on blades inserted and held rigidly in a tap body.

Tap Flutes. — The grooves which extend in a lengthwise direction along a tap in order to provide cutting edges are called flutes. The actual methods

for setting the cutter for fluting must vary according to the form of fluting cutter used, but as a general rule, applying to all forms of fluting cutters, the cutter should be so set with relation to the tap that the cutting face becomes radial. This is the general practice for all taps used on steel or cast iron. When taps are to be used for brass, it is common practice to set the cutter so that the cutting edge is slightly in advance of the radial line, or in other words, parallel to a radial line, but ahead of the center. This provides for a slight negative rake. The amount that the plane of the cutting face should be ahead of the center should be from one-sixteenth to one-tenth of the diameter of the tap.

TAPS, ADJUSTABLE. Adjustable taps are made for the purpose of permitting adjustment to a correct standard size. The adjustable tap may either be made from a solid piece, split in a suitable manner to permit adjustment, or it may be provided with inserted blades or cutters, which are so held in the tap body that a slight movement of these blades in the longitudinal direction of the tap moves the cutting points of the thread nearer or farther from the axis of the tap, thus decreasing or increasing the diameter, as the case may be. There are various designs.

TAPS, COLLAPSIBLE. The collapsing tap shown in the accompanying illustration is one of many different designs that are manufactured. These



Collapsing Tap

taps are often used in turret lathe practice in place of solid taps. When using this particular style of collapsing tap, the adjustable gage *A* is set for the length of thread required. When the tap has been fed to this depth, the gage comes into contact with the end of the work, which causes the chasers to collapse automatically. The tool is then withdrawn, after which the

chasers are again expanded and locked in position by the handle seen at the side of the holder.

As collapsible taps need not be backed out of the hole at the completion of the thread, this reduces the actual tapping time and naturally increases production. While it does not take quite as long to back a tap out as it does to run it into a hole, due to the faster travel of the machine when reversed, yet, when compared with the instantaneous withdrawal of a collapsible tap all the time so consumed can be considered as lost. Saving in time and increase of production ranging from 10 to 100 per cent have frequently been shown.

Different Designs of Collapsible Taps. — Generally speaking, collapsible taps are made in two chief styles — stationary and rotary. Stationary taps are used on such machines as turret lathes, hand screw machines, certain automatic machines, boring mills, and any machine where the tap is held stationary and the work revolves. Rotary taps are used on drill presses, radial drilling machines, tapping machines, certain automatic machines, or any machine on which the work being tapped is held stationary and the tap revolves.

In the stationary style, a lever is employed for expanding the chasers into the cutting position by hand. Frequently this is automatically accomplished by bolting a bar of steel to the turret slide guide, which engages the handle on the backward travel of the turret. The rotary tap can be expanded by arranging a yoke or suitable fixture to the spindle housing to press against a collar or flange provided for the purpose, as the spindle is backed away or withdrawn from the work. This permits setting the chasers while the tap is in motion. The ordinary method of collapsing the chasers is by means of a tripping collar which is set according to the depth of thread desired, and which comes into contact with the face of the work. This is the type shown in the illustration. Several makes of taps are also on the market in which the chasers are collapsed by what is generally known as the "pull off" method. With these taps the turret is retarded either by hand or by stop-screws, and the action of the chasers in pulling on the threads already cut operates a cam, which collapses the chasers.

TAPS, DIE. See Die Taps.

TAPS, GROUND. A notable development in tap manufacture consists in grinding the taps after hardening. The grinding process serves to correct the distortion due to the hardening process and it also leaves the tap with keen cutting edges. The advantages of grinding include accuracy of shape or thread form, accurate lead, as accurate a diameter as is necessary to meet commercial requirements, and the effective use of high-speed steel.

Most ground taps are made from high-speed steel, and the grinding process

after heat-treatment, makes it possible to harden such taps at the high temperatures required to get the best results with steels of this class. There are two general methods of making ground taps. One plan is to machine the tap thread and then correct it after hardening by grinding off the slight amount that has been left for this purpose. The other method is to harden the unthreaded tap blank and then form the entire thread by the grinding operation. It is claimed that this process of grinding "from the solid" permits the nearest approach to the ideal heat-treatment of steel. Ground taps not only provide means of producing accurately threaded holes, but they are capable of exceptionally large production per tap, owing to the use of the properly heat-treated high-speed steel taps which have keen cutting edges. Some ground taps have been made from carbon steel, but the consensus of opinion is that this refined method of finishing taps should only be applied to steels of the high-speed class in order to obtain the best results.

TAPS, HAND. See Hand Taps.

TAPS, REMOVAL OF BROKEN. Of all the numerous ideas which have been applied in removing a broken tap, the use of a mixture of sulphuric and muriatic acid seems to be one of the best. In using this method, the first step is to clean all grease and other foreign matter from the hole, using either gasoline or heat for this purpose. Then apply the acid, a few drops at a time; in doing this, particular care must be taken if the tap is bottomed in the hole. The acid cuts both ways, reducing the size of the tap and enlarging the size of the thread, and after a short time the tap can be easily backed out with an extractor or an ordinary pair of pliers. After the acid has been applied, a constant pressure should be maintained on the tap in order to back it out as soon as possible. The hole is then washed out with water to prevent the metal being attacked any more than is necessary. The use of a little white chalk or alkali in the water is beneficial, as it tends to neutralize the acid and stop all further action. The application of heat will accelerate the rate at which the acid works. Where the tap is bottomed hard, a clearance has to be eaten away by the acid.

One of the many uses to which an electric arc welding outfit may be put is the removal of broken taps from holes in castings. The method employed is very simple, and has been used quite extensively. It consists simply of building metal on the shank of the broken tap within the hole, up to or above the level of the work. Care must be exercised in this building-up operation, to prevent the deposited metal from coming in contact with the threads in the tapped hole. After the shank has been built up in this manner, the head of a bolt or a nut is tacked to the built-up shank and then the tap may be readily backed out in the regular manner. A considerable amount of time

and labor may be saved by this method, and by the exercise of caution the thread will not be injured.

TAP WRENCH. A wrench of this type is used for holding the end of a hand tap or reamer during the process of tapping or reaming; it is always made with two handles in order to assist in centering and to make manipulation easier. Both non-adjustable and adjustable types are employed.

TASK TIME. The predetermined time in which a given job should be performed under the bonus wage system of payment is called the task time.

TAYLOR-WHITE PROCESS. This process of hardening high-speed steel is, briefly, as follows: The first step, commonly known as the "high-heat treatment," is effected by heating the tool slowly to 1500 degrees F., and then rapidly from that temperature to just below the melting point, after which the tool is quickly cooled below 1550 degrees F. At this point, the cooling is continued either fast or slow to the temperature of the air. It is important to avoid any increase of temperature during the cooling period. The second, or "low-heat treatment," consists in reheating a tool which has had the high-heat treatment to a temperature somewhere between 700 and 1240 degrees F., preferably in a lead bath, for a period of five minutes. The tool is then cooled to the temperature of the air either rapidly or slowly.

As there are many high-speed steels on the market, the heat treatment recommended by the steel manufacturer in each case, should be applied.

T-BOLT. See T-slot.

TCHETVERT. This is a Russian measure for capacity, equals 5.96 U. S. bushels, or 2.1 hectoliters.

TEAT DRILL. The cutting edges of a teat drill are at right angles to the axis, and in the center there is a small teat of pyramid shape which leads the drill and holds it in position. This form is used for squaring the bottoms of holes made by ordinary twist drills or for drilling the entire hole, especially if it is not very deep and a square bottom is required. For instance, when drilling holes to form clearance spaces at the end of a keyseat, preparatory to cutting it out by planing or chipping, the teat drill is commonly used.

TEE. A tee is a pipe fitting, either cast or wrought, that has one side outlet at right angles to the run; that is, a single outlet branch pipe. A *cross-over tee* is made along lines similar to a cross-over, but having at one end two openings in a tee-head the plane of which is at right angles to the plane of the cross-over bend. A *union tee* has a male or female union at the connection on one end of the run. A *service tee* has an inside thread on one

end and on the branch, but an outside thread on the other end of the run; it is also known as a *street tee*. A *double-sweep tee* is made with easy curves between body and branch, *i.e.*, the center of the curve between the run and branch lies outside the body.

TEE SECTION. The standard structural section known as a tee has a T shape. See Structural Shapes.

TELEGRAPH. Credit for the invention of the electric telegraph is ordinarily given to Prof. Samuel F. B. Morse of Mass., although this invention, like many other epoch-making inventions, was not the work of one man. The development of the battery, which was an important element in developing the electric telegraph, began with Galvani in 1790, and Volta in 1800, and in 1836 the Daniell battery was invented by Prof. Daniell of London. The fact that electricity could be transmitted through a metallic conductor had been observed many years prior to the invention of the electric telegraph; moreover, in 1837 Prof. Steinheil of Munich discovered the practicability of using the earth as the return section of an electrical circuit. The electromagnet which constitutes such an important part of the electric telegraph, was developed chiefly by Prof. Joseph Henry of Princeton, N. J., although the underlying principle of the electromagnet was first discovered in 1819 by Prof. Oersted of Copenhagen. The Morse register and alphabetical code was the invention of Prof. Morse, and the first United States patent was issued in 1840. The first instrument was designed to draw on a strip of paper zigzag lines, thus providing a visible code. In 1844 a receiving register was adopted which recorded on a paper ribbon a series of dots and dashes, instead of zigzag markings.

TELEPHONE. Prof. Alexander Graham Bell, according to decisions of the Patent Office and courts, was the first inventor of a practical telephone. The first patent was awarded to Prof. Bell in 1876 and the second patent in 1877. Philip Reis in 1861 devised an electric telephone that transmitted musical tones. Various inventors claimed credit for the invention of the telephone and perhaps the most important contestant was Elisha Gray who filed a caveat in the Patent Office upon the same day that Prof. Bell made his application. In the contest which followed with Gray and other inventors, the Patent Office decided that the first practical form of telephone was that of Prof. Bell's, and this decision was later sustained by the courts.

TELESCOPIC GUARD This is a device used for the protection of machine slides, consisting of flat or curved plates having a telescopic action for either opening or closing, depending upon the action of the slide. This guard is used on milling machines and grinding machines — on the former for covering the knee opening and on the latter for preventing water and grit from falling upon the slides.

TELLURIUM. Tellurium is closely related chemically to selenium, and while in appearance wholly metallic, it is not classed among the metals. It is brittle and crystalline and has a silver-white color which is similar to that of unoxidized zinc, and is so soft that it can be scratched by the finger nail. The specific gravity of tellurium is 6.25, the atomic weight, 127.5, and its weight per cubic inch is 0.226 pound. It melts at 452 degrees C. (846 degrees F.) and boils at 478 degrees C. (892 degrees F.). Tellurium is practically a nonconductor of electricity. It has been used for coloring glass, to which it gives a peculiar reddish tint.

TEMPERATURE, ABSOLUTE. See Absolute Temperature.

TEMPERATURE COILS. Thermo-couples or thermostats are resistance coils which are inserted between the coils in electric machinery for measuring the temperature. They may be connected to indicating instruments conveniently located in the station. When the temperature of the indicating coil in the machine rises, the current in that particular circuit decreases due to the increased resistance caused by the heating; this causes a deflection of the indicating needle toward a higher temperature on the scale of the instrument. The reverse occurs when the temperature coil is cooled.

TEMPERATURE CONES. See Seger Temperature Cones.

TEMPERATURE CONTROL, AUTOMATIC. The mechanical devices necessary to obtain automatic temperature control in gas- and oil-fired furnaces consist of (1) a pyrometer or thermostat actuated by the temperature in the oven or furnace; and (2) an automatic valve or switch controlling the fuel input. There are several types of temperature control instruments, each designed for its own particular purpose. For temperatures not exceeding 800 degrees F., a thermostat or thermometer controller may be employed. For higher temperatures — above 800 degrees F. but not exceeding 3000 degrees F. — a pyrometer controller is used.

The control valves that regulate the fuel input may be divided roughly into two classes — the magnet or solenoid type and the motor-driven valves. Some types of magnet valves are operated directly by the pull of the solenoid; in others, the solenoid actuates an air or steam valve, so that the pressure of air or steam is used to actually lift the fuel valve. In one type of motor-driven valve, both the fuel and air valves are operated by one motor. An automatic controlling instrument is used in connection with these valves to measure the temperature of the furnace. Both the valves are adjusted first to give a flame of perfect combustion which, however, will give too low a temperature to bring the furnace up to the desired heat. Later the valves are adjusted to give a higher temperature flame, bringing the heat of the furnace slightly above the temperature required. Then, as soon as the

furnace has reached this higher temperature, the controlling instrument will cause the motor to operate, thereby closing the valve in such a manner that, when a sensitive controlling instrument is used, the furnace can be kept steadily at the required temperature. The fact that greater power is supplied by a motor than by a solenoid makes this type of valve more reliable in operation as compared with the magnetic type; that is, the operation is more positive and less subject to varying influences.

Automatic control can be employed on practically all furnaces and ovens used for hardening, tempering, carburizing, and annealing, both in manufacturing plants and in sheet, rod, wire, and tube mills. Briefly summarized, automatic temperature control, when properly applied, results in better quality and greater uniformity of the product, increased production, decreased cost of furnace repairs, and decreased cost of fuel, due to freedom from waste. See also Pyrometers.

TEMPERATURE INDICATOR. This is an instrument which gives a direct indication of the temperature of the windings of electrical machines. This is accomplished by placing copper coils of known resistance in the parts of the machine to be measured, and showing the change in resistance of the coils on the scale of the indicator, which consists of a differential voltmeter with the scale marked in degrees Centigrade corresponding to the change in resistance.

TEMPERATURES, CRITICAL. See Critical Temperatures.

TEMPERATURES, IGNITION. See Ignition Temperatures.

TEMPERATURE STANDARDS FOR GAGES. Inasmuch as the length of a gage varies somewhat with temperature changes, it is evident that the length should be based upon some standard temperature. In the standardization of precision gages for industrial use, 68 degrees F. has been adopted generally in the United States during recent years as the standard temperature, because it is the common or average working temperature to which gages are ordinarily subjected in practice.

Formerly 62 degrees F. was the temperature used for precision gage standardization, as this is the temperature, approximately, at which the standard yard bar is at the correct length. While 62 degrees F. still applies, of course, to the fundamental standard yard bar in Washington, a temperature of 68 degrees F. is the generally used working standard for the calibration of industrial gages. This temperature not only conforms to average working temperatures, but it has been widely employed for many other physical tests, and moreover, it is the exact equivalent of 20 degrees C.

This same temperature of 20 degrees C., or 68 degrees F., has been adopted as the standard for gage work and other industrial measuring instruments, by engineering standardization bodies in Germany, Holland, Sweden, and

Switzerland. In Great Britain the temperature of 62 degrees F., which applies to the fundamental standard yard bar, is also employed as the basis for industrial gage and instrument calibration.

Standard for Metric Instruments. — Two temperatures — 0 degrees C. (32 degrees F.) and 20 degrees F. (68 degrees F.) — are employed for the industrial standardization of metric measuring instruments. The 0 degrees C. temperature is the standard at which the fundamental standard meter bar is of correct length, but as this temperature is far below ordinary working temperatures, materials having different coefficients of expansion would show measurable differences in length when the temperatures were increased from 0 degrees C. to ordinary working temperatures. For this reason the director of the International Bureau of Weights and Measures recommended the following practice, which, incidentally, has been very generally adopted in France.

Gages and other measuring instruments used in the manufacture of metal parts should be so made that when calibrated at a temperature of 20 degrees C., they will have an assumed coefficient of expansion of eleven millionths per unit of length per degree centigrade. In other words, at 20 degrees C. the actual length of such standards will be 220 millionths per unit of length longer than the corresponding subdivision of the fundamental standard of the meter at 0 degrees C. This assumed coefficient of eleven millionths is approximately correct for steel and cast iron, and the error due to the difference between this arbitrary coefficient and the actual coefficient of ordinary gage materials is so small that it may safely be ignored in industrial gage standardization.

TEMPERING. The object of tempering, or "drawing," is to reduce the brittleness in hardened steel, and to remove the internal strains caused by the sudden cooling in the quenching bath. The tempering process consists in heating the piece of work, by various means, to a certain temperature, and cooling it. The degree of heat to which the tool to be tempered is heated determines the degree of toughness and also the degree of softness. Hardened steel is tempered in order to make it less brittle, but unfortunately the tempering process also softens the steel, to some extent. If it were possible to temper steel so as to produce greater toughness and, at the same time, retain the extreme hardness, the ideal condition would be obtained. That hardness and brittleness are not necessarily synonymous may be seen in the case of cast iron, which is very brittle, but not very hard. On the other hand, there are some alloy steels that may be made very hard and at the same time very tough. The object of tempering steel is to reduce the brittleness; that the hardness is simultaneously reduced cannot, unfortunately, be avoided.

The modern method of tempering, especially in quantity, is to heat the

hardened parts to the required temperature in a bath of molten lead, heated oil, or other liquids; the parts are then removed from the bath and quenched. The bath method makes it possible to heat the work uniformly, and to a given temperature within close limits because the temperature of the bath may readily be determined. While oil is the most widely used medium for tempering tools in quantities, other means and methods are employed, especially by those who have tools in small quantities to temper, when the expense of installing and running an oil tempering furnace would not be warranted.

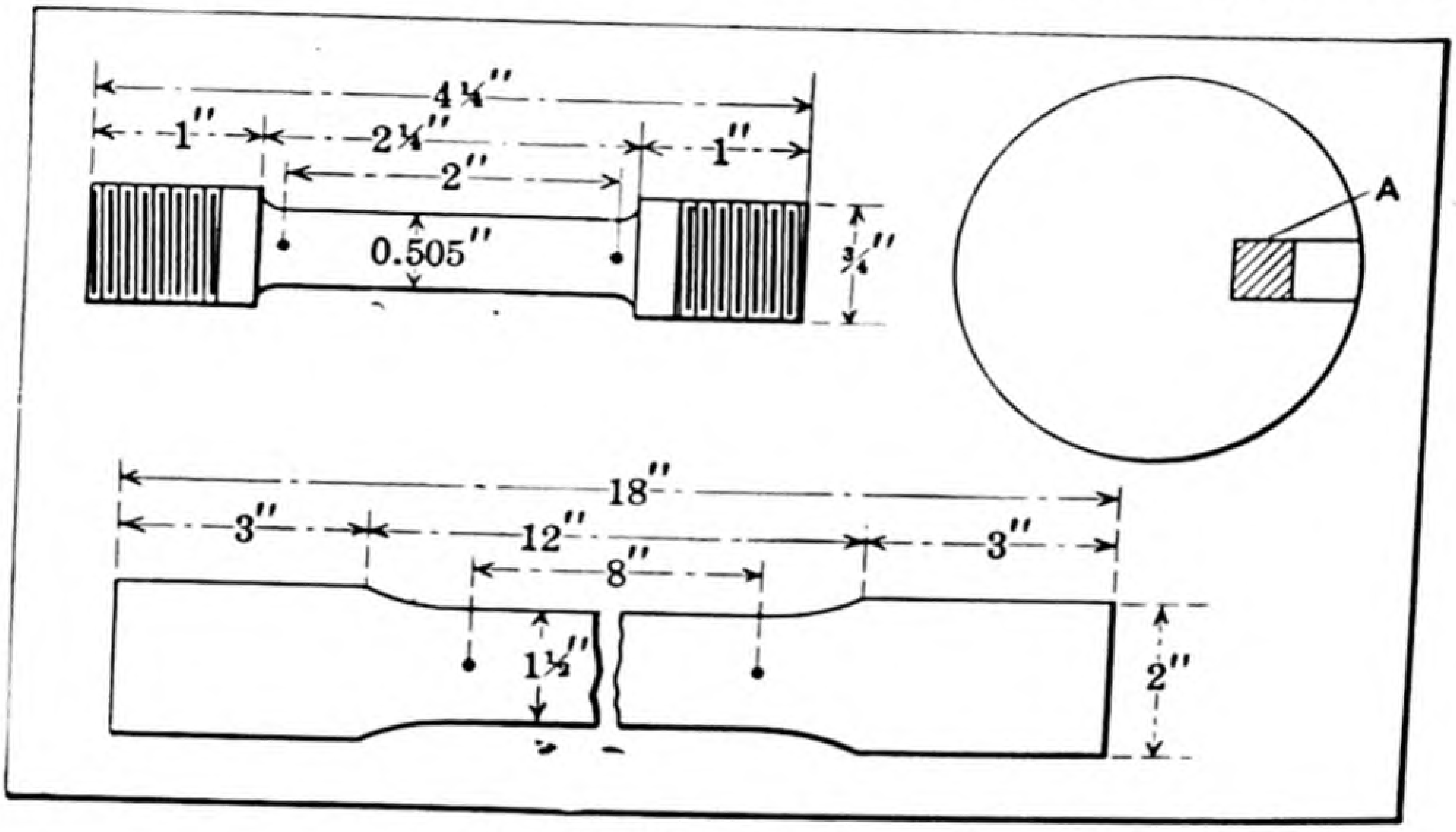
TEMPERING TEMPERATURES. The following temperatures have been recommended by the American Society for Steel Treating for plain carbon tool steel: Temperatures of from 350 to 390 degrees F. are suitable for lathe tools for brass and copper alloys; milling cutters for brass and copper alloys; scraper and cutting tools for soft metals and micarta; drawing mandrels, drawing dies, bone-cutting tools, hammer faces, steel engraving tools, wood-carving tools, cutting tools for iron and steel, hand tools, and threading dies for brass. Temperatures of from 400 to 500 degrees F. are suitable for hand taps and dies, hand reamers, drills, bits, cutting dies, penknives, milling cutters, chasers, inserted sawteeth, press dies for sheet steel, rock drills, taps and dies, wire-drawing dies, dental and surgical instruments, and twist drills. Temperatures of from 500 to 600 degrees F. are suitable for bending and forming dies, shear blades, chuck jaws, forging dies, drifts, gages, press dies, flat drills, reamers, chisels and tools for wood-cutting, hammers and drop dies, axes, lathe tools for copper, augers, cold chisels, coppersmith tools, grinders, screwdrivers, molding and planing tools, hacksaws, needles, butcher knives, and saws.

TEMPORARY HARDNESS. This is a condition of boiler feed water containing carbonates of lime and magnesia. As these are precipitated by heating the water to a temperature of 212 degrees F., the hardness of the water is known as "temporary."

TENSILE TEST. Tensile tests of steel or other materials used in building machines, buildings or other structures, are made with a powerful machine which pulls the standard test specimen apart and indicates the amount of force required. The objects in making tensile tests, are: to determine the elastic limit, the ultimate strength, the elongation, the reduction in area, and the appearance of the fracture.

TENSILE TEST SPECIMENS. The correct selection and preparation of the test specimens for testing are important considerations. In the case of bars, a section at the selected point is turned down to a diameter of 0.505 inch. (See illustration.) This is the standard size and shape for *steel*

tensile test specimens recommended by the American Society for Testing Materials, and is generally used. In the case of large diameter bars, forged shafts, etc., sections to be tested are usually cut out from the bar or shaft parallel to the axis and halfway between the center and the circumference, as shown at *A*. This section is then turned and represents a mean between the material at the center and the circumference. If the quality of the material in a casting is to be determined, a " coupon " (projection) should



Tensile Test Specimens

be cast solid with the main casting; this projection is cut off and turned. (See Arbitration Bar.) When plates or thin bars are to be tested, the specimen should be machined as shown at the lower part of the accompanying illustration. It should be of the full thickness of the material, as rolled, unless the thickness is over 1½ inch, when it may be turned to a diameter of not less than ¾ inch in the center.

The object of reducing the sectional area of the test-bar in the middle is to control the point at which it will break. When reduced, it will always break within the reduced zone, while, if not reduced, it may break at any point along the bar, and frequently within the gripping device. If the latter happens, it probably will be impossible to measure the total elongation of the bar.

Careful machining of the test-bar as to size and finish is essential, to secure reliable results. The finish must leave no tool-marks, else the specimen will break at one of these marks. The turned-down portion must be parallel throughout, or the elongation will not be uniform for the whole length, and the stretch measured will not be the true value.

TENSION SCALES FOR BELTS. The tension of belts used for the transmission of power should be varied according to the length, width, and

thickness of the belt. When a belt is kept at the proper tension, its life is materially increased, and the cost of maintenance and repairs is greatly reduced. A belt should not only have the proper initial tension at the time it is put up, but this tension should be maintained. If a belt is too tight, there is a constant waste of power due to excessive friction in the bearings, and if it is too loose, a loss in efficiency from slippage results; both conditions tend to shorten the life of the belt. A belt tension scale has been designed for testing the tension while a belt is in position on the pulleys. The scale is placed on the belt and a handle is turned, thus causing tension to be applied to the belt by means of a spring contained within the scale. The tension of the belt is indicated by graduations which show whether or not the belt requires tightening, and, if so, how much should be cut out of the belt

TERMINAL PRESSURE. The terminal pressure is the pressure in the cylinder of a steam engine at the time release occurs, and depends upon the initial pressure, the ratio of expansion, and the amount of cylinder condensation.

The terminal pressure of an air compressor is the pressure to which the air is compressed.

TERNARY ALLOY. This is an alloy consisting of three elements. When the term refers to steel, it denotes a steel which contains two alloying elements in addition to iron; since carbon is always present, it is one of these elements. The third element may be nickel, chromium, manganese, tungsten, molybdenum, titanium, or any other element that is alloyed to give the steel some special property.

TERNE-PLATE. Terne-plate differs from tin-plate in that the latter is sheet steel coated with commercially pure tin, while terne-plate or roofing tin consists of sheet steel coated with an alloy of tin and lead. This alloy is usually composed of 32 per cent of tin and 68 per cent of lead; 26 per cent of tin and 74 per cent of lead; or 16 per cent of tin and 84 per cent of lead. Coating the steel with this alloy increases its weight about 20 per cent. Terne-plates are made in sizes of 10 by 14 inches, and in multiples of that measure. The sizes generally used are 14 by 20 inches and 20 by 28 inches. The plates that are coated with an alloy containing from 26 to 32 per cent of tin are generally known as No. 1 terne, while those containing 16 per cent of tin are known as No. 2 terne.

TEST INDICATORS. Test indicators are extensively used in connection with the repair or erection of machinery, for detecting any lack of parallelism between surfaces, in inspection departments, and for testing the accuracy of rotating parts (such as spindles or arbors) in connection with general machine shop and tool-room work. Indicators of the dial type show the varia-

tions in measurement or alignment by the movement of a hand relative to a graduated dial. Other indicators, instead of having a graduated dial, are equipped with a long indicating hand or " finger " which is so connected with the contact point that movements of the latter are considerably magnified.

TESTING BARS. See Tensile Test Specimens; also Arbitration Bar.

TESTING MACHINES. Three general types of machines are used in the United States for testing the materials (steel especially) used in various classes of construction. These are the hydraulic, screw-gear, and " Emery " machines. All of these are universal machines, that is, tensile, compression, and transverse tests can be made on them. The screw-gear type is so named because the pulling is done by screws which are acted upon by gears to produce the motion. These machines are almost universally used in America. The machines of this type are divided into two classes — those having revolving screws with stationary nuts, and those having revolving nuts with non-rotating screws.

TESTS, IMPACT. See Impact Tests.

TETRABASIC ACID. In chemistry, this is an acid which has four atoms of hydrogen in each molecule replaceable by a metal.

THERMAL EFFICIENCY. The thermal efficiency of an engine is the ratio of the heat transformed into work to the total heat supplied. In the case of a perfect engine, working under ideal conditions, the thermal efficiency is given by the formula:

$$\frac{T_1 - T_2}{T_1},$$

in which T_1 = absolute temperature of steam at initial pressure, and T_2 = absolute temperature of steam at exhaust pressure. The absolute temperature may be found by adding 460 to the temperature in degrees Fahrenheit.

As ideal conditions are not possible in practical work, it is customary to employ a formula which takes into account the actual performance of an engine when determining its thermal efficiency. Such a formula takes this form:

$$E = \frac{2550}{W\ (H_1 - q_2)},$$

in which E = thermal efficiency; 2550 = heat equivalent of one horsepower in B.T.U. per hour; W = pounds of steam used per brake horsepower per hour; H_1 = total heat in one pound of steam at initial pressure; and q_2 = heat in liquid at exhaust pressure. For determining the values of H_1

and q_2, a table of the properties of saturated steam is required. See also Efficiency of a Machine; and Mechanical Efficiency.

THERMAL UNIT. This is a unit for measuring quantity of heat, being the amount of heat required for raising the temperature of a certain weight of water one degree on some thermometer scale. In the English system, the British thermal unit is the quantity of heat required to raise the temperature of one pound of pure water one degree F. In the metric system, the French thermal unit, or *calorie*, is the quantity of heat required to raise the temperature of one kilogram of pure water one degree C.

THERMIT WELDING. The thermit process of welding metals is effected by pouring superheated thermit steel around the parts to be united. Thermit is a mixture of finely divided aluminum and iron oxide. This mixture is placed in a crucible and the steel is produced by igniting the thermit in one spot by means of a special powder, which generates the intense heat necessary to start the chemical reaction. When the reaction is once started, it continues throughout the entire mass, the oxygen of the iron being taken up by the aluminum (which has a strong affinity for it) producing aluminum oxide (or slag) and superheated thermit steel. Ordinarily, the reaction requires from 35 seconds to one minute, depending upon the amount of thermit used. As soon as it ceases, the steel sinks to the bottom of the crucible and is tapped into a mold surrounding the parts to be welded. As the temperature of the steel is about 5400 degrees F., it fuses and amalgamates with the broken sections, thus forming a homogeneous weld. It is necessary to preheat the sections to be welded before pouring, to prevent chilling the steel. The principal steps of the welding operation are, to clean the sections to be welded, remove enough metal at the fracture to provide for a free flow of thermit steel, align the broken members and surround them with a mold to retain the steel, preheat by means of a gasoline torch to prevent chilling the steel, ignite the thermit and tap the molten steel into the mold. This process is especially applicable to the welding of large sections. It has been extensively used for welding locomotive frames, broken motor casings, rudder- and stern-posts of ships, crank-shafts, spokes of driving wheels, connecting-rods, and heavy repair work, in general. One of the great advantages of the thermit process is that broken parts can usually be welded in place. For example, locomotive frames are welded by simply removing parts that would interfere with the application of a suitable mold. Thermit is also used for pipe welding, rail welding, and, in foundry practice, to prevent the "piping" of ingots.

THERMOCHEMISTRY. Thermochemistry is that part of the science of chemistry which deals with the heat produced or absorbed by chemical

reactions. Reactions in which heat is evolved are termed *exothermic;* those in which heat is absorbed are called *endothermic*.

THERMOMETER. The thermometer is an instrument for measuring temperature, or the *degree* of heat. It is based upon the principle of the expansion of a liquid, usually mercury or spirits, in a cylinder of small diameter having a bulb at the lower end. Thermometers are used only for measuring comparatively low temperatures, generally not above 200 or 300 degrees F. The instruments used for measuring the degree of heat at higher temperatures are known as *pyrometers*. There are three thermometer scales in general use: The Fahrenheit (F.), which is generally used in the English speaking countries; the Centigrade (C.) or Celsius, which is used in several continental countries and in scientific work; and the Réaumur (R.), which is used to some extent on the European continent, notably in Germany.

In the Fahrenheit thermometer, the freezing point of water is marked at 32 degrees on the scale and the boiling point, at atmospheric pressure, at 212 degrees. The distance between these two points is divided into 180 degrees. On the Centigrade scale, the freezing point of water is at 0 degrees and the boiling point at 100 degrees. On the Réaumur scale, the freezing point is at 0 degrees and the boiling point at 80 degrees.

To find the degrees Centigrade subtract 32 from the degrees Fahrenheit, multiply the remainder by 5 and divide the product by 9. To find the degrees Fahrenheit multiply the degrees Centigrade by 9, divide the product by 5, and add 32 to the quotient.

THERMOMETER FOR HIGH TEMPERATURES. A thermometer capable of temperature readings up to 1000 degrees C. (1832 degrees F.) uses the element gallium, which is sealed in a capillary tube of fused quartz of uniform bore. Gallium melts at 29.7 degrees C. (about 85 degrees F.) and boils at approximately 1700 degrees C. (about 3100 degrees F.). The gallium type of thermometer has been made at the Thompson Research Laboratory of the General Electric Co.

THOMAS-GILCHRIST PROCESS. This is a method for converting pig iron into steel by the Bessemer process. See Bessemer Process.

THREAD ANGLE. The angle of a screw thread is the angle included between the sides of the thread measured in an axial plane. The helix angle is the angle made by the helix of the thread and it depends upon the relation between the diameter of the screw thread and the lead. See Helix Angle.

THREAD CHASERS. A chaser is a form of threading tool having a number of teeth instead of a single point like the threading tools commonly

used for screw cutting in the engine lathe, although the term " thread chasing " is often used to indicate the cutting of a thread with a single-point tool. The two general classes of chasers (exclusive of those used in dies) are hand chasers and threading tool chasers. The former are hand-controlled, and the latter are rigidly held in a tool-holder and used like an ordinary lathe threading tool. When a hand chaser is in use, the cutting end is supported by some form of rest held in the toolpost. These hand chasers are convenient for truing up battered threads or for reducing the size of a part which has been threaded by either a die or a single-point tool. Tools of this kind are especially adapted for brass work. The chaser has teeth spaced to correspond to the pitch of the thread. This form of tool can be applied to the work quickly and without gearing the lathe for a thread-cutting operation.

Chasers Held in Tool-holder. — Threading tool chasers which are held rigidly in the tool-holder are used practically the same as a single-point tool, the lathe being geared for traversing the tool along the work in order to control the lead of the thread. Tools of this kind cut threads rapidly and may be used for roughing out threads preparatory to finishing them with a regular single-point tool. Many screw threads are also finished completely with chasers of this type, although they are not adapted for extremely accurate work unless the teeth are ground after hardening, because the pitch of the chaser teeth is affected more or less by the hardening operation. The pitch of the chaser teeth does not always equal the pitch of the thread to be cut. For instance, a chaser may have a pitch double that of the screw thread. Every alternate groove is engaged, but as the lathe is geared for the pitch of thread to be cut, each tooth of the chaser follows the thread groove the same as though it were a single tool. Chasers are sometimes made in this way for cutting very fine threads, because larger and stronger teeth are obtained.

THREAD-CHASING ATTACHMENTS. Most threading operations in the turret lathe are done by using taps and dies, but, for some classes of work, thread-chasing attachments are used. Such attachments cover a wide range of diameters and may be used, either because the work is too large for a tap or die or because the number of parts required is not large enough to warrant the purchase of special taps and dies. Another advantage of the thread-chasing attachment is that it enables a screw thread to be produced which is known to be true with other cuts that have been taken at the same setting of the work. One of these attachments consists of a reciprocating cutter bar which is carried by a holder that is bolted to the top of the flat turret. Motion is imparted to the cutter bar from the main spindle of the machine through gearing and a splined transmission shaft, which enables the turret to be indexed without interfering with the attachment.

Another form of chasing attachment which is applied to a flat turret lathe consists of a leader or short lead-screw which is mounted upon the feed-rod of the machine, and a brass follower that is engaged or disengaged by a lever pivoted in a bracket bolted to the left-hand end of the carriage apron. A bar carrying a single-point chasing cutter is held in a holder clamped onto the flat turret.

THREAD CHASING DIAL. A thread chasing dial or indicator is a simple device which is attached to the carriage of a lathe and used when cutting threads to enable the operator to engage the carriage with the lead-screw at the proper time, so that the thread tool will follow the original or first cut. The chasing dial consists of a graduated dial and a worm-wheel which meshes with the lead-screw so that the dial is revolved by the lead-screw when the carriage is stationary, and, when the carriage is moved by the screw, the dial remains stationary. The number of teeth in the worm-wheel driving the dial is some multiple of the number of threads per inch of the lead-screw, and the number of teeth in the worm-wheel, divided by the pitch of the screw, equals the number of graduations on the dial. For example, if the lead-screw has six threads per inch, the worm-wheel could have twenty-four teeth, in which case the dial would have four divisions, each representing an inch of carriage travel, and, by subdividing the dial into eighths each line would correspond to $\frac{1}{2}$ inch of travel. The dial, therefore, would enable the carriage to be engaged with the lead-screw at points equal to a travel of one-half inch. If the thread being cut had nine threads per inch, or any other odd number, the tool would only coincide with the thread at points 1 inch apart. Therefore, the carriage can only be engaged when one of the four graduations representing an inch of travel is opposite the zero mark or arrow, when cutting odd threads; whereas even numbers can be "caught" by using any one of the eight lines, assuming that the dial were graduated as described.

THREAD CREST, ROOT, AND BASE. The crest of a thread is the top surface joining the two sides of a thread. The bottom surface joining the sides of two adjacent threads is called the root. The bottom section of the thread or the greatest section between the two adjacent roots is the base of the thread.

THREAD-CUTTING CHANGE-GEARS. See Change-gears for Thread-cutting.

THREAD-CUTTING DIES. See Dies for Thread-cutting.

THREAD-CUTTING METHODS. The two general methods of forming screw threads may be defined as the cutting method and the rolling or dis-

placement method. The cutting methods as applied to external threads are briefly as follows:

1. By taking a number of successive cuts with a single-point tool that is traversed along the part to be threaded at a rate per revolution of the work depending upon the lead of the thread. (Common method of cutting screw threads in the engine lathe.)

2. By taking successive cuts with a multiple-point tool or chaser of the type used to some extent in conjunction with the engine lathe and on lathes of the Fox or monitor types.

3. By using a tool of the die class, which usually has four or more multiple-point cutting edges or chasers and generally finishes the thread in one cut or passage of the tool.

4. By a single rotating milling cutter, which forms the thread groove as either the cutter or the work is traversed axially at a rate depending upon the thread lead.

5. By a multiple rotating milling cutter which completes a thread in approximately one revolution of the work.

6. By a multiple rotating cutter which also has a planetary rotating movement about the work which is held stationary. See Planamilling and Planathreading.

Internal screw threads, or those in holes, may or may not be produced by the same general method that is applied to external work. There are three commercial methods of importance, namely:

1. By the use of a single-point traversing tool in the engine lathe or a multiple-point chaser in some cases.

2. By means of a tap which, in machine tapping, usually finishes the thread in one cut or passage of the tool.

3. By a rotating milling cutter of either the single or the multiple type.

Dies operated by hand are frequently used for small and medium-sized parts, especially when accuracy as to the lead of the thread and its relation to the screw axis is not essential and comparatively few parts need to be threaded at a time. When a large number of pieces must be threaded, power-driven machines equipped with dies are commonly employed. If the operation is simply that of threading the ends of bolts, studs, rods, etc., a " bolt cutter " would generally be used, but if cutting the thread were only one of several other operations necessary to complete the work, the thread would probably be cut in the same machine performing the additional operations. For instance, parts are threaded in turret lathes and automatic screw machines by means of dies and in conjunction with other operations. When screws are required which must be accurate as to the pitch or lead of the thread, and be true relative to the axis of the work, a lathe is generally used; lathes are also employed, ordinarily, when the threaded part is com-

paratively long and large in diameter. Many threads which formerly were cut in the lathe are now produced by the milling process in special thread-milling machines. The method often depends upon the equipment at hand and the number of parts to be threaded.

THREAD, " DRUNKEN." See " Drunken " Thread.

THREAD GENERATING MACHINE. A machine known as a thread generator for generating threads on worms, hobs and similar parts operates on the molding-generating principle, using a helical gear-shaper cutter. The work rotates on an axis at right angles to that of the cutter, and the cutter rotates in unison with the work; that is, the work and cutter are geared together in relation to the number of teeth in the cutter and the number of threads on the worm. The cutter is carried in a head mounted on a slide that is traversed longitudinally along the work, and as the cutter is rolled in mesh with the work, it produces threads by the generating process.

THREAD HOBBING. A hob is sometimes used in conjunction with a gear-hobbing machine for milling multiple screw threads. A hob used for this purpose has teeth which lie along a helical path, like a hob intended for cutting spur or helical gears, and it must be geared to revolve with the work at a definite speed ratio, the same as when hobbing a gear. The hobbing method is particularly efficient for cutting worms having several threads, because the hob finishes the different threads simultaneously.

THREADING ATTACHMENTS, COARSE. See Coarse Threading Attachments.

THREAD MEASUREMENT, THREE-WIRE METHOD. A method for measuring accurately the pitch diameter by means of ordinary micrometers and three wires of equal diameter has long been used. The three wires are arranged as follows: One wire is placed in the angle of the thread on one side of the screw, and the other two on the opposite side, measuring over the whole with a micrometer. In order to determine if the pitch diameter of a screw is correct, first ascertain what the micrometer reading should be, when using wires of a given size, and then compare the actual measurement over the wires with the calculated dimension.

U. S. Standard. — To determine the micrometer reading (M) for a U. S. Standard thread, multiply 1.5155 by the pitch (P) of the thread; subtract the product from the standard outside diameter of the screw and then add to the difference three times the diameter (W) of the wires used. The result equals the micrometer reading if the pitch diameter of the thread is correct.

Whitworth. — To determine the micrometer reading (M) for a Whitworth Standard thread, multiply 1.6008 by the pitch (P) of the thread; subtract

the product from the standard outside diameter of the screw and then add to the difference 3.1657 times the diameter (W) of the wires used. The result equals the micrometer reading if the pitch diameter is correct.

Wire Sizes. — For U. S. Standard threads, smallest wire diameter = 0.56 × pitch; largest wire diameter = 0.90 × pitch; diameter for pitch-line contact = 0.57735 × pitch.

For Whitworth threads, smallest wire diameter = 0.54 × pitch; largest wire diameter = 0.76 × pitch; diameter for pitch-line contact = 0.56368 × pitch.

THREAD MICROMETER. The pitch diameter or angle diameter of a screw thread may be determined by using a special thread micrometer. This micrometer has a fixed anvil which is V-shaped so as to fit over the thread while the movable point or spindle is cone-shaped at the end so that it will enter the space between two threads. The anvil and the spindle make contact with the sides of the thread, thus enabling the "angle diameter" or pitch diameter to be determined.

THREAD MILLING. There are two general methods of forming screw threads by milling, which may be designated as the single-cutter and the multiple-cutter methods. Whenever a single cutter is used, the axis of the cutter is inclined in order to locate the cutter in line with the thread groove at the point where the cutting action takes place. The lengthwise traversing movement is applied to the cutter on some machines and to the screw being milled on other machines. The single-cutter process is especially applicable to the milling of large screw threads of coarse pitch and the heavier classes of work. For fine pitches and short threads, the multiple-cutter method is preferable because it is more rapid. The object of using a multiple cutter instead of a single cutter is to finish a screw thread complete in approximately one revolution of the work. In order to finish the thread complete in one revolution, (plus a slight amount of over-travel) it is necessary to use a cutter which is at least one or two threads or pitches wider than the thread to be milled. In using a multiple cutter it is simply fed in to the full thread depth and then either the cutter or screw blank is moved in a lengthwise direction a distance equal to the pitch of the thread. See also Planathreading.

THREAD ROLLING. The rolling process of forming screw threads may be defined as an impression or displacement method, since the thread grooves are not cut by an edged tool but are formed by means of a die or roll having threads or ridges which are forced into the metal and, by displacing it, produce a thread corresponding to the required shape and pitch. The plain blanks upon which threads are to be rolled are somewhat smaller in diameter than the finished thread, because the rolling process displaces a certain

amount of metal which is forced up above the original surface of the blank, thus producing a screw thread which is larger in diameter than the original blank. The increase in diameter is approximately equal to the depth of one thread. No material whatever is removed by the rolling process, the metal from the depression formed by the die simply being forced up on either side. When screw threads are produced by the rolling or displacement method, there are two general processes:

1. By rolling the blank in contact with a revolvable disk or roll, the periphery of which has either a single thread or a multiple thread corresponding in pitch to the thread required. This method is employed when threads are rolled in automatic screw machines.

2. By rolling the blank in contact with flat dies having parallel ridges which are spaced in accordance with the required pitch and which form the screw thread. Machines designed exclusively for rolling screw threads on such parts as machine screws, bolts, wood screws, etc., are equipped with flat dies.

3. By the rotary or circular method. In a type of thread rolling machine employing this method a cylindrical die, rotating on its axis and provided with thread grooves on the outside, is set horizontally within a hollow cylindrical die having threads on the inside. Screw threads that are within the range of the rolling process may be produced more rapidly by this method than in any other way, which accounts for the use of thread-rolling machines in connection with bolt and screw manufacture.

THREAD-ROLLING STEEL. Soft steel containing from about 0.07 to 0.12 per cent carbon is suitable for thread rolling. Iron of ordinary quality is not adapted for the thread rolling process because of its fibrous structure, which makes it likely to split or fracture as a result of the pressure caused by the thread rolling operation. One company recommends the use of "liquor"-finish soft steel wire, claiming that this material will give the best results with the minimum of wear on both the header and the thread rolling dies. If the "liquor"-finished wire cannot be obtained, a good grade of annealed and cleaned wire may be employed. Another concern recommends the use of wire of the following composition: Carbon, 0.08 to 0.12 per cent; manganese, 0.35 to 0.45 per cent; phosphorus, 0.03 to 0.04 per cent; and sulphur, 0.03 to 0.04 per cent. This material has a tensile strength of about 56,000 pounds per square inch. Bright basic wire is one of the best and cheapest materials obtainable, and is suitable both for heading and cold roll threading. This material is hard enough to permit a slot to be cut after the heading operation by means of a slotting machine. The bright basic wire can be obtained in small quantities and from the mill in lots of 2000 pounds or more. It is generally best to obtain it from the mill, as the quality is likely to be more uniform.

Tolerances. — The wire mills will accept a tolerance specification of plus or minus 0.002 inch on the diameter. It is particularly important that this tolerance be maintained on stock used for long screws of small diameter. On screws of short length the material will flow, and if the wire is over-size little trouble will be experienced, but in the case of screws having a length greater than ten times their diameter, the material will be confined, and "burning" will take place, if the tolerance is greater than that specified. If the wire is slightly under size, the rolled threads will have a very ragged appearance due to the fact that the crest is not fully formed. On screws under the 10–24 size, a tolerance of plus or minus 0.001 inch must be adhered to in order to insure good results.

THREAD-ROLLING WIRE DIAMETER. The diameter or size of wire to use for thread-rolling may be obtained by the following rule. To find the diameter of the unrolled blank, subtract from the pitch diameter of the screw, one-eighth of the thread depth for a U. S. Standard Thread. This rule is intended for use when screw threads are rolled on bright basic wire.

THREE-SQUARE FILES. These files are made in taper, slim, and blunt forms. They are double-cut, mostly bastard, and used quite extensively for filing angular surfaces, and for many other purposes. The three sides are of equal width, the angles between them being 60 degrees.

THREE-WIRE METHOD OF THREAD MEASUREMENT. See Thread Measurement, Three-wire Method.

THROAT OF BLAST FURNACE. The throat of a blast furnace is the upper part or opening through which the ore and fuel are charged into the furnace and which is closed by a bell or cone-shaped device which prevents the escape of the blast furnace gases. The throat is usually about two-thirds of the diameter of the largest part of the furnace at the upper end of the section which is known as the *bosh.*

THROAT OF DIE CHASER. The throat of a die chaser is the chamfered portion at the leading end of the chaser provided to enable the die to enter readily upon the work to be threaded and distribute the thread-cutting operation over at least two or three chaser teeth.

THROW, ECCENTRIC. See Eccentric.

THRUST BEARING. The term thrust bearing is usually applied to bearings designed primarily for supporting a shaft against a load acting parallel to the axis, the bearing taking an end thrust. Some thrust bearings have plain sliding surfaces, whereas others are of the anti-friction type and are equipped either with ball or roller bearings. The thrusts having sliding surfaces may be divided into two general classes known as step bearings and

collar bearings. Step bearings support a shaft at its end, as for example, when a vertical shaft rests in a step bearing. Such bearings often have a number of disks or washers to increase the number of wearing surfaces. Some step bearings are supplemented by high-pressure lubrication so that the shaft is hydraulically supported. Collar thrust bearings are so named because the shaft has projections or shoulders which engage several bearing surfaces, thus distributing the thrust load over these annular ridges or rings about the shaft.

THURBER RULE. This is a rule employed for finding the board measure of logs, as follows: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply the result by the length of the log in feet. The diameter inside of the bark at the small end is measured usually.

THURY REGULATOR. The Thury regulator is used in electrical machinery for maintaining constant voltage by field resistance control. The field rheostat is not actuated directly by the voltage fluctuations, but is operated by a small electric motor, the regulating mechanism being merely brought into play or stopped by the fluctuations of voltage.

THURY SYSTEM. The Thury system is a high-voltage direct-current transmission system for electric power. It consists of a number of constant-current commutator type generators which are connected in series to develop the desired transmission voltage. Instead of the current varying with the load, as in the constant-potential alternating-current system, the voltage varies with the load, the current remaining constant. At the distributing end of the system, a series of motors similar to the generators must be used, and each one of these motors must drive an alternating- or direct-current generator for the usual constant-potential distribution.

TIDAL POWER PLANTS. The idea of utilizing the rise and fall of the tides for generating power has long been discussed, although no tidal power station of any magnitude has yet been developed. The lack of data based on operating conditions and on constructional costs renders it difficult to form any definite conclusions as to the economic aspects of such a scheme. The only practicable methods of developing tidal power on any large scale are based on the use of one or more tidal basins, separated from the sea by dams or barrages, and of hydraulic turbines through which the water flows on its way between the basin and the sea, or between one basin and another.

TIE-BOLT. See Bolts.

TILLER OR HAND ROPE. This is a wire rope consisting of 6 ropes wound into one main rope. Each of the 6 ropes forming the main rope

has 6 strands with 7 wires each. This construction produces an exceedingly flexible rope which can be bent over very small sheaves. It is one of the most flexible standard ropes obtainable, but as it is made from very fine wire, it will not stand much surface wear, and, therefore, should not be subjected to heavy loads.

TILTED TURRET. The turrets of most turret lathes revolve about a vertical axis, although, in many cases, the turret is inclined or set at an angle relative to the turret-slide and bed. On one tilted-turret machine, the turret is tilted toward the spindle at an angle of 15 degrees, so that a tool such as a boring-bar or die will be at an angle of 30 degrees from the horizontal when in the rear position. This change in the position of the tools as they are indexed toward the rear enables tools of larger diameter to be used, which is one of the advantages of the tilted turret. Each hole in the turret is continued in a straight line from one side to the other, and there is also a hole through the central turret stud so that it is possible for long bars to extend clear through the turret, when a hollow form of tool is being used. This feature enables long stock to be handled without using a tool having an excessive overhang. Owing to the inclined position of the turret, the strain on the central stud is also reduced, owing to the fact that part of the endwise thrust of the cutting tools is taken directly by the angular surface of the turret-slide. Several different makes of large turret lathes are equipped with turrets which are inclined toward the rear of the machine, instead of toward the spindle, so that long cutter bars, etc., will be at their highest point when passing the front of the machine. Turrets are mounted in this way for providing clearance between the tools and the large pilot wheel or turnstile which is used for operating the turret-slide by hand.

TIME-LIMIT DEVICE. A device used in connection with overload electric circuit-breakers when it is desired to prevent the tripping of the circuit-breaker due to momentary overload or rushes of current at starting. These time-limit devices usually consist of an oil or air dashpot so arranged that the desired time delay is secured by a very small movement of the armature. If the overload persists until the predetermined time is exceeded, the circuit-breaker is tripped.

TIME STUDY. That part of "scientific management" which is concerned with the time required for doing certain work is referred to as *time study*. Time studies may be divided into two kinds: Simple time studies, in which the time element only is analyzed, and complete time studies, which include motion studies or an analysis of the various motions required for performing certain work. Complete time studies, therefore, include observation of wasteful methods and inefficiency and their elimination; standardization of conditions and operations; the setting of the tasks to be per-

formed by the workmen; and the determination of the reward to be given for individual efficiency. It naturally also includes the making of estimates on work to be made and the ascertaining of costs in advance. In properly conducted systems of scientific management, time studies are not undertaken with a view to speed up or drive the workmen, but with the idea of standardizing approved methods by means of which the work should be done, so that the workmen may be able to accomplish more work without greater exertion.

TIN AMALGAM. This is an alloy of tin and mercury, used for silvering mirrors.

TIN AND ITS PROPERTIES. Tin is a soft metal of white color, almost entirely devoid of tenacity. Its specific gravity varies according to the treatment; cast tin has a specific gravity of about 7.29, rolled tin, 7.30, and electrically deposited tin, from 7.14 to 7.18. Tin melts at a temperature of 232 degrees C. (450 degrees F.), and boils at a temperature of about 1600 degrees C. (about 2900 degrees F.). Its specific heat is 0.056, and its coefficient of linear expansion per unit length, per degree F., is 0.000015. Its thermal conductivity is about 15 (silver = 100), and its electrical conductivity, about 13 (silver = 100). If tin is exposed for any length of time to very low temperatures (−40 degrees F., for several hours), it becomes so brittle that it disintegrates into a powder. Tin is used in its pure state in the chemical industries for containers, stills, etc. It is employed for making tin foil, for silvering mirrors, for wrapping food products, and for tinning cooking utensils, because it is proof against acid liquids. The most important uses of tin in the industries, however, are in the various alloys which it forms with copper, antimony, and lead. Bronze is, perhaps, the most well known of these alloys, it being composed of copper and tin, the copper content being usually from 80 to 90 per cent, while the remainder is tin. The greater part of tin produced is employed in the making of tin alloys. Tin is the only one of the more important metals that is not produced in the United States to any appreciable extent. The Federated Malay States, Bolivia, and the Dutch East Indies produce the bulk of the world's supply of tin.

TIN FOIL AND LEAD FOIL. Lead foil consists of lead with a very light tin coating, whereas tin foil is made of practically pure tin. The production of lead foil, in a plant where large quantities of both lead and tin foil are manufactured, is as follows: Cast ingots of lead about 24 inches square and 1 inch thick are passed through the first break-down mill, thus reducing the ingot thickness to about $\frac{1}{2}$ inch and increasing the length to about 42 inches. A casing or covering of pure tin, about $\frac{1}{64}$ inch thick, is next placed on the top and bottom of the ingot which is then passed through the next break-

down mill. Two more passes, or four in all, reduce the ingot to a thickness of about $\frac{1}{16}$ inch and increase the length to approximately 40 feet, after which one pass is usually all that is required in the finishing mill. Lead foil, common foil or "four per cent" as it is sometimes called, contains about 4 per cent tin and 96 per cent lead.

Tin foil, which is made from cast ingots of tin, is produced by the same general process, although tin foil is given eight passes through the finishing mill. Tin foil is usually mounted on wax paper, but when food products are packed with foil alone, pure tin foil must be used.

According to the practice in another plant, lead foil, briefly described, is made in the following manner: First a tin pipe is made of such proportions as to give, in subsequent processes, the required relative thickness between the tin coating and the covered lead sheet. This pipe is then filled with molten lead, and, after cooling, rolled or beaten to the extreme thinness required. In this process, the tin coating spreads simultaneously with the spreading of the lead core and continuously maintains a thin even coating of tin on each side of the center sheet of lead. It is possible in this manner to reduce the thinness of the lead sheet to one-thousandth inch or less, and still retain an uninterrupted tin coating.

TIN PLATE. Tin plates are made by coating soft sheet steel with tin to protect the steel from corrosion. They are made in sizes of 10 by 14 inches and multiples of that measure, the most commonly used sizes being 14 by 20 and 20 by 28 inches. The "base weight" of tin is equivalent to the weight of a standard "base box" which contains 112 sheets of 14- by 20-inch size. In the trade, the expressions "charcoal plates" and "coke plates" are retained from the time when high-grade tin plates were made from charcoal iron and the lower grade of tin plates from sheet iron produced with coke as a fuel, or coke iron. At the present time, however, these terms refer only to the quality of the tin coating and the finish. Charcoal plates have the heaviest coating and the highest polish, while coke plates have a light coating of tin. The latter are generally used for can-making. The amount of coating of pure tin per square foot of plate equals 0.023 pound, according to the specifications of one large consumer of this material. See also Terne-plate.

TIRE BOLT. A bolt having a countersunk head at one end and a thread for about one and one-half or two times its diameter for a square or hexagon nut at the other end.

TITANIUM. Titanium is one of the metallic chemical elements, the symbol of which is Ti, and the atomic weight, 48.1. Titanium has a brilliant white fracture and is harder than steel. Its specific gravity varies from 4.5

to 4.9. It melts at a temperature of 1900 degrees C. (3452 degrees F.). Its specific heat is 0.112. Titanium is most commonly found associated with iron in various iron ores.

TITANIUM STEEL. Titanium is one of the elements that have been employed with marked success to improve the quality of steel. It has also been very successfully used for cast iron and for some of the non-ferrous metals. The first heat of titanium steel made in America was poured in 1907, and since that time a great deal of investigation has been conducted and many experiments have been made. These tests have shown that, when ferrotitanium has been added to steel or iron in very small quantities, it has greatly strengthened these metals and improved their qualities in other ways; it is one of the best of the purifying elements that have been used in the manufacture of steel. The special properties of this steel are in its ability to resist abrasive or frictional wear. In a test made on titanium-steel rails, it was found that, under similar conditions, an ordinary Bessemer rail would wear five times as much during an equal period of time. Titanium steel has been used for gears, tires, and castings in general, and has almost invariably shown a reduction of brittleness and an increase of durability. Titanium tool steels are also used, it having been found that if 0.5 per cent of titanium is present in steel, cutting tools are produced which give much greater dura bility and high-grade quality.

Endurance Tests. — The endurance of titanium-treated steel has been demonstrated by tests on a rotary vibrational testing machine. An open-hearth steel that contained 0.25 per cent of carbon, 0.64 per cent of manganese, 0.425 per cent of silicon, 0.04 per cent of phosphorus, and 0.035 per cent of sulphur, withstood 2,660,000 revolutions at a fiber stress of 38,870 pounds. After this same steel had been treated with titanium, it was given 4,052,200 revolutions at the same fiber stress, namely, 38,870 pounds. The stress was then increased to 40,600 pounds, and the piece stood 10,800,700 additional revolutions without a fracture. The fiber stress was again increased to 42,400 pounds and the piece given 1,918,600 more revolutions. The stress was increased a third time to 44,200 pounds and the piece was given an additional 1,006,300 revolutions before it broke. This was a total of 17,777,800 revolutions for the titanium steel, many of which were given it at an increase of fiber stress, as against 2,660,000 revolutions for the untreated steel.

TITRATION. In analytical chemistry, titration is the process of ascertaining the quantity of any given constituent present in a compound, by observing the quantity of a liquid of known strength (called a standard solution and usually added from a burette) necessary to convert the constituent into another form, the close of the reaction being marked by some

definite phenomenon, such as a change of color or the formation of a precipitate. Titration is also called volumetric analysis.

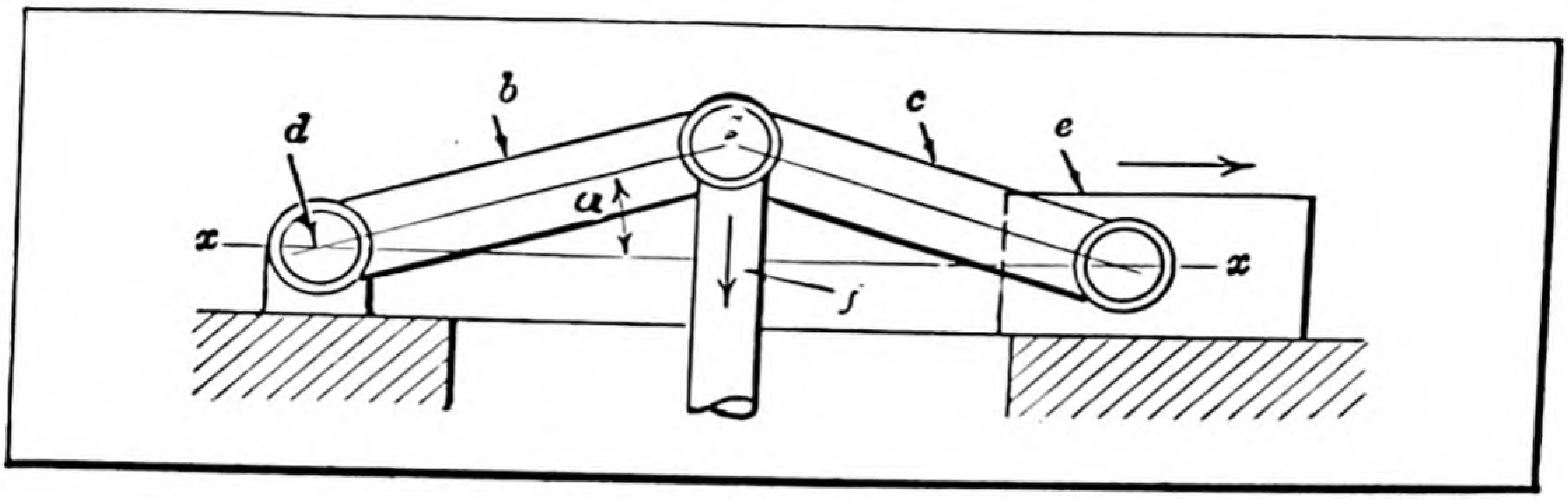
TOBIN BRONZE. Tobin bronze is a special bronze containing from 59 to 63 per cent of copper and from 0.5 to 1.5 per cent of tin, the remainder being zinc, with the exception of small quantities of other ingredients which are added to improve the quality of the metal. On account of the tensile strength of Tobin bronze and its resistance to the corrosive action of sea water, it is extensively used in marine work for such parts as condenser plates, pump piston-rods, valve stems, valve faces, pump plungers, pump linings, motor-boat shafting, condenser tube plates, etc. When used in the form of bolts, rods, and plates, its resistance to wear and oxidation makes it a most useful material for chemical extract works, tanneries, sugar houses, coal mines, etc. The melting point of Tobin bronze is 1600 degrees F. It can be welded electrically or with a high-temperature welding flame. The nonliability of Tobin bronze to produce sparks makes it valuable for powder press plates and powder mill tools. It has a specific gravity of 8.4 and the weight per cubic inch is 0.3036 pound. The ultimate tensile strength varies from 60,000 to 65,000 pounds per square inch, and the compressive strength from 170,000 to 180,000 pounds per square inch.

TOGGLE-DRAWING PRESS. Double-action toggle-drawing presses are preferable to drawing presses of the cam type, in all cases where the blanks have been previously cut (even though the stock may be heavy), or where the metal to be cut and drawn simultaneously is of comparatively light gage. The inner plunger of the toggle-drawing press is actuated by the main crankshaft, and the outer blank-holder slide receives its motion from two rockshafts connected by a system of links with the main shaft. This form of drive imparts a more uniform pressure to the blank than is possible with cam-operated drawing presses.

TOGGLE JOINT. A link mechanism commonly known as a toggle joint is applied to machines of different types, such as drawing and embossing presses, stone crushers, etc., for securing great pressure. The principle of the toggle joint is shown by the accompanying diagram. There are two links, b and c, which are connected at the center. Link b is free to swivel about a fixed pin or bearing at d, and link c is connected to a sliding member e. Rod f joins links b and c at the central connection. When force is applied to rod f in a direction at right angles to center-line xx, along which the driven member e moves, this force is greatly multiplied at e, because a movement at the joint g produces a relatively slight movement at e. As the angle α becomes less, motion at e decreases and the force increases until the links are in line. If R = the resistance at e; P = the applied power or

force; and α = the angle between each link and a line xx passing through the axes of the pins, then:

$$2 R \sin \alpha = P \cos \alpha.$$



Toggle Joint Principle

TOLERANCES. Tolerance is the amount of variation permitted on dimensions or surfaces of machine parts. The tolerance is equal to the difference between the maximum and minimum limits of any specified dimension. For example, if the maximum limit for the diameter of a shaft is 2.000 inches and its minimum limit 1.990 inches, the tolerance for this diameter is 0.010 inch. By determining the maximum and minimum clearances required on operating surfaces, the extent of these tolerances is established. As applied to the fitting of machine parts, the word tolerance means the amount that duplicate parts are allowed to vary in size in connection with manufacturing operations, owing to unavoidable imperfections of workmanship. Tolerance may also be defined as the amount that duplicate parts are permitted to vary in size in order to secure sufficient accuracy without unnecessary refinement. The terms "tolerance" and "allowance" are often used interchangeably, but, according to common usage, *allowance* is a difference in dimensions prescribed in order to secure various classes of fits between different parts.

Unilateral and Bilateral Tolerances. — The term "unilateral tolerance" means that the total tolerance, as related to a basic dimension, is in *one* direction only. For example, if the basic dimension were 1 inch and the tolerance were expressed as 1.00 − 0.002, or as 1.00 + 0.002, these would be unilateral tolerances, since the total tolerance in each case is in one direction. On the contrary, if the tolerance were divided, so as to be partly plus and partly minus, it would be classed as "bilateral." Thus, $1.00^{+0.001}_{-0.001}$ is an example of bilateral tolerance, because the total tolerance of 0.002 is given in two directions — plus and minus.

When unilateral tolerances are used, one of the three following methods should be used to express them:

(1) Specify limiting dimensions only as

Diameter of hole: 2.250, 2.252

Diameter of shaft: 2.249, 2.247

(2) One limiting size may be specified with its tolerances as

Diameter of hole: $2.250 + 0.002, -0.000$

Diameter of shaft: $2.249 + 0.000, -0.002$

(3) The nominal size may be specified for both parts, with a notation showing both allowance and tolerance, as

Diameter of hole: $2\frac{1}{4} + 0.002, -0.000$

Diameter of shaft: $2\frac{1}{4} - 0.001, -0.003$

Bilateral tolerances should be specified as such, usually with plus and minus tolerances of equal amount. Example of the expression of bilateral tolerances follow:

$$2 \pm 0.001 \quad \text{or} \quad 2\begin{array}{l}+0.001\\-0.001\end{array}$$

How to Apply Tolerances. — According to practice approved by the Society of Automotive Engineers, tolerances should show the permissible amount of variation in the direction that is less dangerous. When a variation in either direction is equally dangerous, a bilateral tolerance should be given. When a variation in one direction is more dangerous than a variation in another, a unilateral tolerance should be given in the less dangerous direction. One exception to the use of unilateral tolerances on mating surfaces occurs when tapers are involved. In such cases either bilateral or unilateral tolerances may prove advisable, depending upon conditions.

Where tolerances are required on the distances between holes, usually they should be bilateral, as variation in either direction is usually equally dangerous. The variation in the distance between shafts carrying gears, however, should always be unilateral and plus; otherwise the gears might run too tight. A slight increase in the backlash between gears is seldom of much importance.

Basic Dimensions. — The minimum hole should be of basic size in all cases where the use of standard tools represents the greatest economy. The maximum shaft should be of basic size in all cases where the use of standard purchased material, without further machining, represents the greatest economy, even though special tools are required to machine the mating part.

Standardization in Different Countries. — National standard systems of fits have been established in the United States, Austria, Germany, Great Britain, Holland, Sweden, and Switzerland. All national standards, except the British, are based exclusively on the unilateral system of tolerances. The British standard gives both the unilateral and the bilateral systems,

recommending the former. The national standards, with the exception of the American, the British, and the Dutch, give both the basic hole and the basic shaft systems. The United States and Great Britain have adopted the basic hole system, Holland the basic shaft system exclusively. The Dutch system is at one extreme, in affording the maximum freedom of choice in the combination of hole and shaft. It specifies limits only, and does not give allowances or tolerances. The other extreme is formed by the type of system adopted by the Austrians, Germans, Swedes, and Swiss, which gives a number of fits completely defined by their allowances and tolerances. The American system lies between these two extremes. The standard reference temperature for gages is 20 degrees C., or 68 degrees F., in all the countries mentioned, except Great Britain, where it is 62 degrees F.

TOLERANCES, GAGE. See Gage Tolerances.

TON. One net or short ton = 2000 pounds (commonly used in the United States and Canada); 1 gross or long ton = 2240 pounds (commonly used in England and for certain purposes in the United States).

TON, METRIC. See under Metric System.

TOOL CHECKING SYSTEMS. In every tool store-room it is essential to have some systematic method of determining what tools are in use and where they are located in the shop, to prevent loss of tools and to enable any tool to be found readily if necessary. The method which has been adopted almost universally is to use brass checks which are numbered to correspond with numbers given to different workmen. These checks may be placed in the store-room tool cabinet where the tool belongs, or they may be filed on a board in the store-room, so that the number of tools in the possession of any particular workman may readily be determined. There are various modifications of this checking system which are intended either to simplify the system, or to make it a more effective means of accounting for tools and of preventing mistakes or fraudulent practices.

Single Check System. — The single check system, as commonly applied to tool-rooms, is so arranged that each workman has a certain number of checks which he receives when first employed. These checks, as previously mentioned, are stamped with the employe's number, and whenever he obtains a tool from the store-room, a check must be given to the tool-room attendants as a receipt. This check, according to the usual method, is placed on a hook located where the tool belongs in the bin, rack or drawer of the cabinet. When the tool is returned to the tool-room the check is given back to the workman. If the tool should be sent from the tool-room to the grinding department or forge shop, a special tool-room check is either

put in its place or a written record is kept; consequently, the location of every tool not in the store-room is shown either by the number of the workman's check or by a tool-room check or a separate record.

Double Check System. — When a single check is exchanged for a tool and is placed where the tool belongs in the tool cabinet, it might be impossible for the man in the tool supply room to determine how many tools a workman has in his possession without examining the entire stock of tools, providing there were no separate record. The double check system shows the number of tools received by each workman and for that reason is preferred in some plants. With one system there is a board in the tool store-room which has two check hooks for each employe and near each pair of hooks there is a label giving the name of the employe and the corresponding check number. When a man is engaged by the concern he is given a certain number of round checks, and a corresponding number of square checks are hung on one of the hooks opposite his name on the store-room board. Whenever a workman receives a tool, he gives a round check in exchange for it and this check is placed on the hook adjacent to the man's name and number. At the same time, a square check from the opposite hook is removed and inserted in that part of the tool cabinet from which the tool was taken. When this tool is returned, the square check is replaced on the board and a round check on the other hook is given back to the workman. With this system the number of round checks hanging opposite each name shows how many tools that particular man has in his possession, without searching through the tool cabinet. The square checks, which are also numbered, show who received the tools that are not in the tool racks.

TOOL-GRINDING MACHINES. The turning and planing tools used in lathes, planers, etc., are ground in special tool-grinding machines in many shops, instead of by the workmen on an ordinary grinding wheel. These machines are designed to hold and guide the tool mechanically, as it is brought into contact with the grinding wheel. When these tool grinders are used, the tools which have been sharpened by them are kept in a tool- or storage-room, and each workman obtains from this stock of tools as many as may be required. There are several important advantages connected with the grinding of tools by means of these special machines. In the first place, when the tools are ground in this way, it is not necessary for the workman to stop his machine and go to a grinding wheel; moreover, a machine designed especially for this class of work makes it possible to grind all the tools to standard angles of slope and clearance, which have been found to give the most efficient results. With this system of sharpening and storing the tools, a smaller stock will be required, which is another important advantage.

TOOL-HOLDERS. The tools used in lathes, planers, and other turning and planing machines may either be forged to shape from a bar of steel and form a solid one-piece tool or such tools may consist of tool-holders into which relatively small pieces of steel are clamped so as to form the cutting point or end. The practical introduction of tool-holders began in about 1866, when W. Ford Smith, of Manchester, England, in a paper read before the Institution of Mechanical Engineers, described a system of tool-holders for cutting metals. Some of these tool-holders were adapted for round cutters made from ordinary bar steel and others for cutters of a deep V-section having a rounded bottom edge. The use of tool-holders and inserted cutters gradually spread until, at the present time, tools of this type are used very extensively, and for many classes of work they have replaced the solid forged tools. A typical form of tool-holder, such as is used for turning operations, consists of a drop-forged shank or holder in which a small tool-steel cutter is clamped. One of the important advantages of this arrangement is that very much less tool steel is required than when the entire tool is forged from a solid bar of tool steel; consequently, the expense for tool steel is very much less in shops equipped with tool-holders, especially at the present time when costly high-speed steels have so generally replaced carbon steels. The expense of forging and reforging solid tools is also eliminated when tool-holders are used, since the cutters are of uniform section and are simply adjusted outwards as the ends are ground away.

TOOLMAKER'S LATHE. Lathes of this class are made with a greater degree of precision than ordinary engine lathes, and are more expensive; they are equipped with special attachments which adapt them to the varied line of work connected with toolmaking. Among the features which are common to a toolmaker's lathe may be mentioned the taper attachment, the collet chuck in the spindle, and the relieving attachment for backing off the teeth of milling cutters.

TOOLMAKER'S MICROSCOPE. A toolmaker's microscope is designed for general use in checking both linear and angular measurements in connection with screw threads, gages, small jigs, and various classes of precision work. One make consists of a microscope mounted vertically above a compound table having longitudinal and lateral movements controlled by accurate micrometer screws. These screws have a range of 1 inch, and they are graduated to read to 0.001 inch. Parts to be inspected are either held in a special attachment or placed directly upon the table in the field of observation, within which is a "spider-line cross" and angular graduations.

In checking a screw thread, the axis of the screw is first located parallel with the cross-line. Either the outside or root diameters may then be checked by adjusting the table laterally until the cross-line coincides with

either the top or root of the thread on the opposite side, and then noting the difference between the readings on the micrometer. To obtain the thread depth, the cross-line would be set to coincide first with the top of the thread, and then with the root, the difference in readings representing the depth. To check the pitch, the intersection of the cross-lines would be set to coincide with the slope of the thread at some point, after which the table would be moved longitudinally to obtain the same intersection with the adjacent thread. For checking the angle of a screw thread, or other angular work, one cross-line is set on the 30-degree division; the table is then adjusted longitudinally until the side of one thread intersects or coincides with the cross-line.

TOOLPOST GRINDING ATTACHMENT. See Grinding Attachment, Toolpost.

TOOL STEEL. Tool steel, as the term is used in the machine-building industry, may be defined in a general way as any steel that is suitable to be used as a cutting tool, or a steel which contains a sufficient amount of carbon so that it will harden if heated above a certain temperature and rapidly cooled. This broad definition includes, under the head of tool steel, both high-speed steels and plain carbon steels. Steel for many of the cheaper grades of tools and implements is made by the open-hearth process but is known as " tool steel."

The crucible process was formerly used for making all the high-grade tool steel used for metal-cutting tools and, consequently, the terms " tool steel " and " crucible steel " are often used interchangeably, but at the present time the electric furnace is used extensively for producing tool steel which should not be classified as crucible steel.

Crucible or tool steel is made by adding carbon to high-grade wrought iron containing as small a percentage of phosphorus as possible. Small pieces of wrought iron are placed in air-tight crucibles containing the required amount of powdered charcoal. This charge is then melted in a furnace and the metal cast into ingots, which are hammered and rolled to the required size. If the steel is to contain chromium, tungsten, etc., these ingredients are also added in the crucible. The adding of carbon to wrought iron, in order to convert it into tool steel, gives the latter the property of being capable of hardening; that is, of assuming greater hardness if heated to a given temperature and then quenched in water or oil.

Tools of Carbon Steel. — Steel with a carbon content of from 0.65 to 0.80 per cent is suitable for shear blades, boiler snaps, and cups, hammers, stamping and pressing dies, and mining drills. Steel with a carbon content of from 0.81 to 0.95 per cent is suitable for hot and cold sets, chisels, dies, shear blades, mining drills, blacksmiths' tools, swages, flatteners, and set-

hammers. Steel with a carbon content of from 0.96 to 1.10 per cent is suitable for small cold chisels, hot sets, small shear blades, large pincers, large taps, granite drills, trimming dies, turning tools, planer tools, drills, cutters, slotting and milling tools, mill picks, circular cutters, small shear blades, and threading dies. Steel with a carbon content of from 1.11 to 1.25 per cent is suitable for small milling cutters, small taps, drills, slotting and planing tools, wood-cutting tools, turning tools, and razors.

TOOL STEEL, OPEN-HEARTH. See Open-hearth Tool Steel.

TORQUE. The torque of a motor is its turning moment and it is generally expressed as the number of pounds of effort exerted at a radius of 1 foot. To find the horsepower that is equivalent to a given torque and speed of rotation, the following formula may be used, in which H = horsepower; T = torque at 1 foot radius; and R = revolutions per minute.

$$H = \frac{T \times R \times 2 \times 3.1416}{33,000} = \frac{T \times R}{5252} \qquad T = \frac{H \times 5252}{R}$$

TORSIONAL TEST. This test is made by gripping a bar at each end; one end is held rigidly and the other is twisted while a weighing device indicates the twisting force required.

TORUS. A torus or ring is a circular or ring-shaped body having a circular cross-section. The circular end link often used on a chain, for example, is mathematically known as a *torus*.

TOU. A Chinese capacity measure, legalized in 1908, equal to 10.35 liters or 2.736 gallons.

TOWER'S EXPERIMENTS. These are a series of experiments that were undertaken to determine the effect of friction in bearings, according to which the following laws were formulated: 1. Temperature and velocity remaining constant, the friction coefficient is proportional to the nominal pressure, and the work done against friction is independent of the load, providing this does not exceed from 400 to 600 pounds per square inch. 2. Nominal pressure and velocity remaining constant, the coefficient and, therefore, the work done against friction is inversely proportional to the temperature of the bearing.

TRACE. The expression "trace," in a chemical analysis, refers to an amount of an element too small to be determined exactly. It is possible, by taking a large quantity for the analysis and by the very highest refinement in the work, to actually weigh a trace, but in ordinary work it is not done, nor is it usually necessary. In ordinary commercial analysis, it is customary to carry out the percentages of the various ingredients to one-hundredth of one per cent (0.01 per cent), but further than this, except in

exceptional cases, it is deemed unnecessary. A substance present in this quantity is very small, and is generally considered as the limit of practical analytical determination, so that less than 0.01 per cent is usually too small to determine, and is called a "trace." A trace of an ingredient is, therefore, an amount which is present in the substance analyzed, but is too small to admit of quantitative determination.

TRACING CLOTH. Tracing cloth is largely used for the original drawings of machine parts, etc. in order to make blueprints from the fairly transparent tracing. It is made of finely woven and very smooth cloth, coated with a preparation for the purpose of giving it a fine surface for the use of the pen, and also rendering it transparent. One side is smooth and glossy while the opposite side usually has a dull finish. Drawings may be made on either side. It is easier to erase inked-in lines on the glossy side, but it does not take the ink as well, and the surface should be prepared before inking by rubbing powdered chalk or talcum powder into it with a cloth or chamois skin. It is easier to ink-in a drawing on the dull side, but it is more difficult to make changes.

TRACING PAPER. Tracing paper (thin, transparent paper) from which blueprints may be made, is very useful for temporary work, or when there is to be very little handling of the tracing. There are tracing papers, such as bond paper, vellum, or parchment paper, etc., that are strong enough to stand considerable hard usage. Some of the best classes of tracing papers are very tough, transparent, and strong and may, for many purposes, be substituted for tracing cloth.

TRACTION SPROCKET. A traction sprocket, also known as face sprocket, is a sprocket used with a detachable link-belt when the chain makes a reverse bend, so that the open end of the link rides on the sprocket. The base diameter of such a sprocket must be greater than that in an ordinary link-belt sprocket, the pitch diameter remaining the same. The teeth of traction sprockets generally have a sharp point, to distinguish them from the standard sprockets.

TRACTIVE FORCE. The tractive force of a locomotive of the single expansion (not compound) type may be determined as follows: Multiply the square of the cylinder diameter in inches by the piston stroke in inches, and multiply the product by 85 per cent of the boiler pressure in pounds per square inch; then divide this total product by the diameter of the driving wheels in inches. If the locomotive is a two-cylinder compound, multiply together the square of the low-pressure cylinder diameter, the piston stroke, the boiler pressure, and a constant of 0.52, assuming that the cylinder ratio is about 2.5 to 1; then divide this total product by twice the

diameter of the driving wheels. The *draw-bar pull* of a locomotive is, as the name indicates, the power that a locomotive is capable of exerting at the draw-bar and for pulling the train; hence, the draw-bar pull is somewhat less than the tractive force, as the latter includes the power required to overcome the resistance of the locomotive itself.

TRACTRIX. The curve known as a *tractrix*, frequently also called the "Schiele" curve or the "anti-friction" curve, has been supposed to give the correct outline for an end-thrust bearing, because the wear in the direction of the axis of the thrust shaft will be uniform at all points when the pivot is given the form determined by this curve. It has been shown, however, that the merits of a pivot bearing shaped in this manner have been greatly over-estimated; and the term "anti-friction," applied to the curve, is a misnomer, since the friction of the bearing designed in accordance with it is greater than that of a flat step or collar of the same diameter.

TRADEMARK. A trademark is an arbitrary sign, word, or symbol used to distinguish one manufacturer's product from that of another, and to impress a particular article on the mind of the public. The value of a trademark consists of an assurance to a manufacturer or merchant of protection in the exclusive use of the name, sign, or symbol, by which his product becomes known. The trademark is a guarantee of the genuineness of the marketed article, and may be said to be, in this respect, the commercial substitute for an autograph. The protective value of the trademark may be compared with the protection afforded by a fundamental patent, as the trademark is used not only in connection with patented articles but also with commodities not patented nor patentable.

A trademark must not in any way be descriptive of the product nor should it be in the least deceptive. For instance, if a trademark for a soap were claimed on the word "Magnetic," the claim would be rejected on two grounds. First, because soap could not be magnetic, and so the word would be deceptive and misleading, and second, because the term would be descriptive if correctly employed. A proper name, geographical term, or the name of cities, etc., also cannot be used as trademarks. The first letters in the words of a company's name are frequently used with the abbreviation of company. For example, a coined word such as "Seeco" is arbitrary and meaningless, and it would be proper subject matter for a trademark, provided it had not been used previously. Trademarks can be registered in the United States Patent Office, so that the manufacturer who is the maker of well-known trademarked products is protected against the use of his trademark by competitors. The use of an unregistered trademark is upheld by the common law, but when registered there is *prima facie* evidence of ownership. The decision of one U. S. Court, should litigation develop, will in most cases be given full credit in all of these courts.

TRADE TERMS. Owing to the confusion that often arises due to misinterpretation of the terms and abbreviations used in export trade, and the consequent trade disagreements, a conference of leading national trade organizations was held, at which definitions of export terms were adopted and general recommendations made for a standard American export practice. The following five abbreviations are those most commonly used in export quotations:

F. O. B.	Free on board
F. A. S.	Free alongside ship
C. & F.	Cost and freight
C. I. F.	Cost, insurance and freight
L. C. L.	Less than carload lot

F. O. B. (Named Point). — This term is used when the price quoted applies only at inland shipping point and the seller merely undertakes to load the goods on or in cars or lighters furnished by the railroad company serving the industry, or most conveniently located to the industry, without other designations as to routing. Under this quotation the seller must (1) place goods on or in cars or lighters; (2) secure railroad bill of lading; and (3) be responsible for loss or damage until goods have been placed in or on cars or lighters at forwarding point, and clean bill of lading has been furnished by the railroad. The buyer must (1) be responsible for loss or damage incurred thereafter; (2) pay all transportation charges including taxes, if any; and (3) handle all subsequent movement of the goods.

F. A. S. Vessel (Named Port). — This term is used when the seller desires to quote a price covering all expenses up to and including delivery of the goods within reach of the vessel's loading tackle. Under this quotation the seller must (1) transport goods to seaboard; (2) store goods in warehouse or on wharf if necessary, unless buyer's obligation includes provision of shipping facilities; (3) place goods alongside vessel either in a lighter or on the wharf; and (4) be responsible for loss or damage until goods have been delivered alongside the ship or on wharf. The buyer must (1) be responsible for loss or damage thereafter, and for insurance; (2) handle all subsequent movement of the goods; and (3) pay cost of hoisting goods into vessel where weight of goods is too great for ship's tackle.

C. & F. (Named Foreign Port). — This term is used when the seller is ready to go further than the delivery of his goods upon the overseas vessel and is willing to pay transportation to a foreign point of delivery. Under this quotation the seller must (1) make freight contract and pay transportation charges sufficient to carry goods to agreed destination; (2) deliver to buyer or his agent proper bills of lading to the agreed destination; and (3) be responsible for loss or damage until goods have been delivered along-

side the ship and clean ocean bill of lading obtained (seller is not responsible for delivery of goods at destination).

The buyer must (1) be responsible for loss or damage thereafter and must take out all necessary insurance; (2) handle all subsequent movement of the goods; (3) take delivery and pay costs of discharge, lighterage and landing at foreign port of destination in accordance with bill of lading clauses; and (4) pay freight customs duties and wharfage charges, if any.

C. I. F. (Named Foreign Port). — This term is used when the seller desires to quote a price covering the cost of the goods, the marine insurance on the goods, and all transportation charges to the foreign point of delivery. Under this quotation the seller must (1) make freight contract and pay freight charges sufficient to carry goods to agreed destination; (2) take out and pay for necessary marine insurance; (3) be responsible for loss or damage until goods have been delivered alongside the ship, and clean ocean bill of lading and insurance policy have been delivered to the buyer, or his agent. (Seller is not responsible for the delivery of goods at destination, nor for payment by the underwriters of insurance claims); and (4) provide war risk insurance, where necessary, for buyer's account.

The buyer must (1) be responsible for loss or damage thereafter, and must make all claims to which he may be entitled under the insurance directly on the underwriters; (2) take delivery and pay costs of discharge, lighterage and landing at foreign port of destination in accordance with bill of lading clauses; and (3) pay foreign customs duties and wharfage charges, if any.

TRAIN OF MECHANISM. Any series of gears, links, cams, chain drives, belt drives, etc., used to transmit motion (regardless of their order or combination) is known as a train of mechanism. If motion is transmitted entirely through gearing, the combination of gears is called a *gear train.* Trains of gears, pulleys, etc., are common to all classes of mechanisms and may be necessary either for obtaining a required velocity ratio or for transmitting motion when the driving and driven members are so located that a more direct method of transmission is not practicable. Motion is often transmitted through trains of gearing specially arranged so that speed changes may readily be obtained by manipulating suitable controlling levers.

TRAM CRANE. This type of crane is similar to a traveling crane, except that the bridge is very short and not provided with a trolley, so that the load can be moved only in the direction of the bridge itself which travels longitudinally on over-head rails.

TRANSFER CALIPER. A caliper provided with an auxiliary arm which can be located so that the calipers may be opened or closed to the original setting, if required. Calipers of this type are generally used for inside

measurements, and are employed for measuring recesses where it is necessary to move the caliper points in order to remove the calipers from the place where the measurement is taken.

TRANSFORMER. An electrical transformer, also known as a "static transformer," may be defined as a stationary (not rotary) apparatus for changing alternating currents of a given voltage into current of a higher or lower voltage. The possibility of changing the voltage of the current is of great importance, because, in most cases, the economical voltages for generating, transmitting, and using electric power are all different. Fundamentally, the alternating-current transformer is very simple. If alternating current is passed through a coil called the "*primary*," an alternating magnetic field is set up. If another coil, called the "*secondary*," is placed close to the primary coil, the magnetic field induces in the secondary coil a voltage directly proportional to the number of turns. The product of primary volts times primary amperes is equal to the product of secondary volts times secondary amperes. Thus the kilovolt-amperes in the primary and the kilovolt-amperes in the secondary are equal, except for small losses in the apparatus. In very small transformers, the heat due to the internal losses is dissipated without undue rise of temperature, and no special provision need be made for it. In medium- and large-sized units, some special arrangement must be made to dissipate the heat without too great a rise of temperature. With reference to the method of cooling, transformers of considerable size are classified as oil-cooled, water-cooled, and air-blast.

TRANSFORMER RATIO. The ratio of a transformer, unless otherwise specified and according to the standardization rules of the American Institute of Electrical Engineers, shall be the ratio of the number of turns in the high-voltage winding to that in the low-voltage winding; *i.e.*, the "turn ratio." The "voltage ratio" of a transformer is the ratio of the r.m.s. (root mean square) primary terminal voltage to the r.m.s. secondary terminal voltage, under specified conditions of load. The "current ratio" of a current-transformer is the ratio of r.m.s. primary current to r.m.s. secondary current, under specified conditions of load. The "marked ratio" of an instrument transformer is the ratio which the apparatus is designed to give under average conditions of use. When a precise ratio is required, it is necessary to specify the voltage, frequency, load and power factor of the load. The volt-ampere ratio of transformers, which should not be confused with real efficiency, is the ratio of the volt-ampere output to the volt-ampere input of a transformer, at any given power factor.

The circuit voltage has no effect on the ratio of a current transformer. For example, if the transformer is designed for 500 amperes on the primary to 5 on the secondary, this ratio holds true whether it is connected to a 110-

volt circuit or a 11,000-volt circuit. The only difference in current transformers designed for high- and low-voltage circuits is in the insulation between primary and secondary windings and between primary and ground. This must be heavy enough to prevent puncture.

TRANSIT. The transit is an instrument used in surveying for measuring both horizontal and vertical angles, although for ordinary work the vertical attachment is omitted. This instrument consists of a telescope mounted in standards which are attached to a horizontal plate called the "limb." Inside of the limb, and concentric with it, is another plate called the "vernier plate." The lower plate, or limb, turns on a vertical spindle or axis which fits into a socket in the tripod head. By means of a clamp and tangent screw, it may be clamped fast in any position, and made to move slowly through a small arc. The circumference of this plate is usually graduated in divisions of either one-half or one-third of a degree, and in the common form of transit these divisions are numbered from some one point on the limb in both directions around to the opposite point which will be 180 degrees. The graduation is generally concealed beneath the plate above it, except at the verniers. This upper plate is the vernier plate, which turns on a spindle fitted into a socket in the lower plate. It is also provided with a clamp by means of which it can be held in any position, and with a tangent screw by which it can be turned through a small arc. The transit generally is provided with a compass, so that the bearing of any given line with the magnetic meridian may be determined, if desired. It also has a spirit level attached to the telescope, so that it may be brought to a horizontal position and made to serve as a level.

TRANSLATING GEARS. When a lathe is to be used for cutting threads in accordance with both the English and metric systems of measurements, what are known as "translating gears" are sometimes used. These gears have 50 and 127 teeth, respectively, these numbers representing the relation between the English and metric systems of measurement; thus, 1 inch is equivalent to 2.54 centimeters, and $\frac{1 \times 50}{2.54 \times 50} = \frac{50}{127}$. By inserting these gears in the train of gearing connecting the lathe spindle and the lead-screw, it is possible to gear the lathe for cutting a given number of threads per centimeter, the translating gears being used in addition to the same gears that would be employed for cutting a similar number of threads per inch.

TRANSMISSION DYNAMOMETERS. See Dynamometers.

TRANSMISSIONS, HYDRAULIC. See Hydraulic Transmissions.

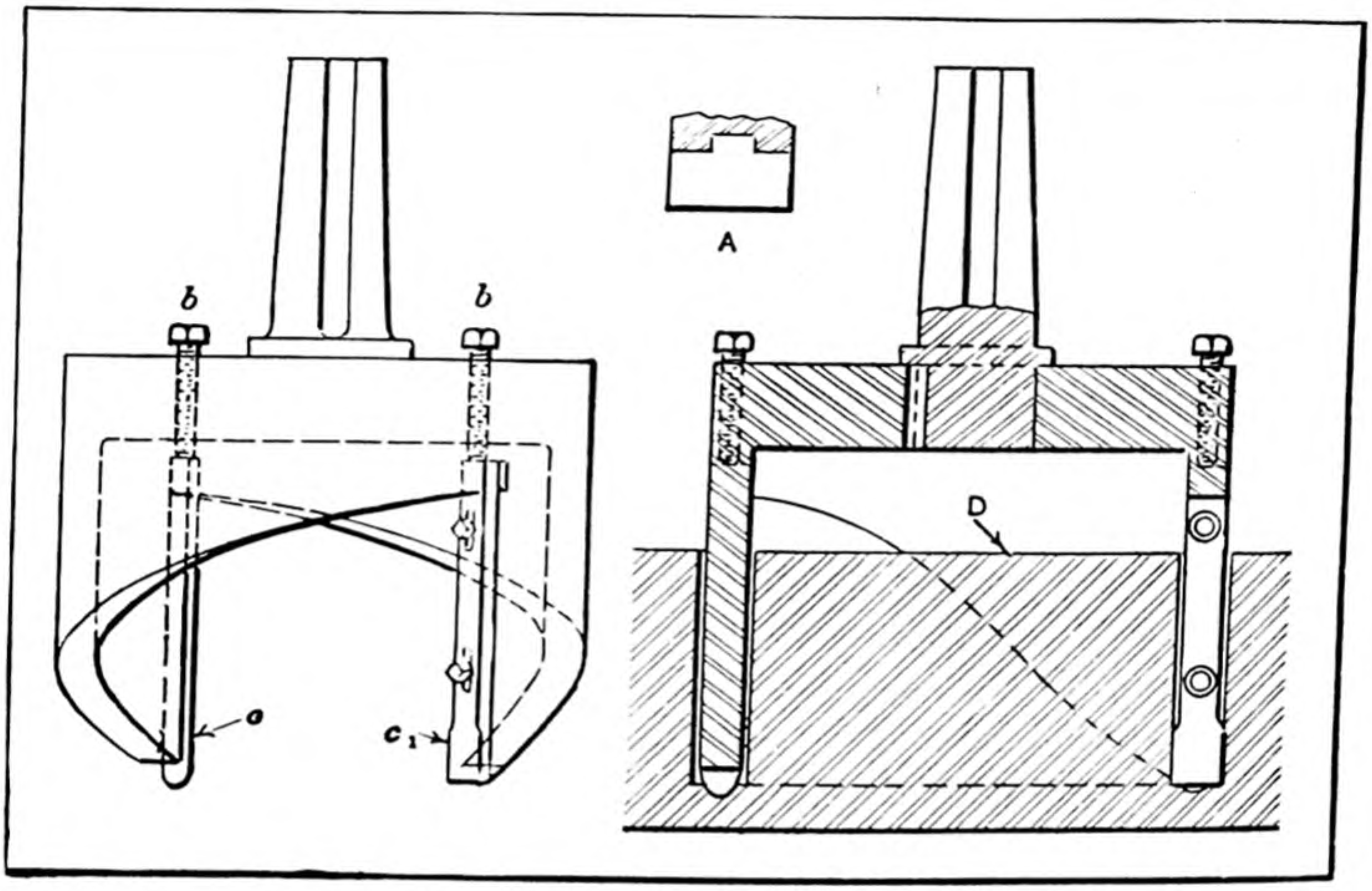
TRANSVERSE TEST. A transverse test is made by placing a bar over two supports, loading the bar midway between the supports, and observing the amount of load required to bend or break the test specimen.

TRAPEZOID AND TRAPEZIUM. A plane figure bounded by four straight lines, of which only two are parallel, is called a *trapezoid.* A plane figure bounded by four lines, no two of which are parallel, is called a *trapezium.* These definitions of trapezoid and trapezium, while they are most commonly used in the United States and sanctioned by several standard dictionaries, are not definitely established as mathematical expressions. There are some dictionaries of the English language in which the definitions of trapezoid and trapezium are interchanged. This is particularly the case in dictionaries published in Great Britain.

TRAVELING CRANE. This is a crane for raising and lowering loads in which there is, in addition to the lifting motion, provision for two horizontal movements at right angles to one another, so that the load can be picked up or deposited at any point within a rectangle formed by the movement of the crane. A traveling crane consists mainly of a bridge or girder spanning the bay of a shop or foundry or a space over a yard, this bridge moving longitudinally on over-head tracks provided at its ends. On this bridge is mounted a trolley or crab which moves in a transverse direction along the bridge. These two movements provide for motion in two directions at right angles to each other.

TREPANNING. When a comparatively large hole must be cut " from the solid " a trepanning tool is sometimes used. This tool is so designed that it forms a hole by cutting a narrow groove, the central part or core being taken out as a solid piece. The trepanning tool has two inserted cutters c and c_1 (see illustration) which are mounted in a head of such a form as to provide a strong support and, at the same time, give ample chip room — a matter of importance when taking a cut of this kind. Each tool is located and firmly held by a tongue that engages a groove cut in the holder as indicated by the detail view A. The tools are held in place by tap bolts, which pass through slotted holes. The vertical adjustment of the tools is effected by means of screws b passing down from the top of the holder. This adjustment permits setting the cutters so that they will be in a position relative to each other for working to the best advantage. As indicated by the sectional view to the right, this tool, as it is fed down through the forging, removes a solid block of metal D, thus forming a large hole with the expenditure of comparatively little power, since the tools do not have to remove very broad chips. One of these tools has a round cutting edge and the other one a square edge. With this arrangement, the round tool cuts a central

groove, whereas the square tool cuts away the sides, thus forming a channel wide enough to clear the tool-holder. By grinding the tools in this way, the work of cutting is distributed.



Trepanning Tool for Large Holes

TRIANGLES. A triangle is a plane figure bounded by three straight lines. If all the three sides of a triangle are of equal length, it is known as *equilateral*. If two sides are of equal length, it is known as *isosceles*. If one angle is a right, or 90-degree angle, the triangle is a *right* or *right-angled* triangle. If all the angles are less than 90 degrees, the triangle is an *acute* or *acute-angled* triangle. If one of the angles is larger than 90 degrees, the triangle is an *obtuse* or *obtuse-angled* triangle.

TRIANGLES FOR DRAFTING. When a T-square is used for drawing horizontal lines, in connection with mechanical drawing, vertical and inclined lines are usually drawn with the aid of triangles. A common form of triangle has one angle of 90 degrees and two angles of 45 degrees, and another common form has one angle of 90 degrees and the other two of 30 and 60 degrees.

TRIBLET. It is necessary to control the inside diameter of a drawn tube, as well as the outside, otherwise the reduction would all take place from the outside and leave the walls of the tube very thick. In order to properly gage the inside of the tube while it is being drawn through the die, the inside is kept from closing in by the insertion of a steel mandrel or "triblet." This

triblet is a rod which is slightly smaller in diameter than the tube over which it is drawn, and must be of a length longer than any tube that will be drawn over it. To the end of the triblet is welded a hardened steel tip, the shape and size of which gage the inside of the tube. At its opposite end it is secured to the center of a bar that has a sliding action of five or six inches over two bolts in the standard of a bench at the rear.

TRIGONOMETRIC FUNCTIONS. See Functions of Angles.

TRIMMER. A trimmer is usually a hand-operated machine and is used in patternmaking and other wood-working shops, for squaring ends, trimming the ends of segments, etc. It is provided with a scale for cutting the miters of all regular polygons.

TRIMMING DIES. Drop-forgings require trimming after the forging proper is done. The forging comes from the dies with a small amount of fin evenly distributed all around the forging, at the parting line and this fin is removed by the trimming dies. Trimming dies are of two general classes; namely, *hot-trimming* dies and *cold-trimming* dies, according to the condition of the forgings when trimmed. There is a special grade of steel, commonly known as *hot-trimming die-stock*, that is used for making hot-trimming dies. This special steel requires no hardening. Cold-trimming dies are made from tool steel containing from 1.00 to 1.25 per cent carbon, and then hardened and drawn to a dark straw color.

TRINITRO-TOLUENE. Trinitro-toluene is a commonly used high explosive. As its name indicates, it is a combination of trinitryl and toluol. It is much less dangerous to manufacture or handle than either picric acid or nitro-glycerine, as its fumes are not injurious nor is it sensitive to shock. Heat and moisture have little or no effect upon it, and it refuses to combine with the metals or their oxides. From toluene is obtained saccharine, which is approximately five hundred times sweeter than sugar. In use, the nitro-toluene is melted and poured into the steel or iron shell, where it solidifies, and is exploded by a time or percussion fuse.

TRIPLE-ACTION DIE. See Drawing Dies.

TRIPLE-POLE CIRCUIT-BREAKER. This type of circuit-breaker is used on a three-wire direct-current, and on three-phase and quarter-phase three-wire alternating-current circuits.

TRIPLEX CABLE. See Cable.

TRIPPING MECHANISMS. What are known as " tripping " mechanisms are applied to various kinds of machinery to stop the movement either of the entire machine or of some part of it. Automatic tripping

devices generally operate in conjunction with a clutch, or they are used to disengage intermeshing gears. The trip may be adjustable and be set beforehand to act after a certain part has moved a given distance, or it may only act when a machine begins to operate under abnormal conditions. The adjustable form of trip, if for a part having a rectilinear motion, may consist simply of a stop which is placed in such a position that it will disengage a clutch after the part under the control of the trip has moved the required distance. If a rotary motion is involved, the same principle may be applied with whatever modification of the mechanism is necessary. If the trip is designed to act automatically only when the machine is operating under adverse conditions, the action may be governed by variations of pressure or resistance to motion; the product on which the machine is working may also cause the trip to act in case the operation is not as it should be.

TRIP, REVERSE-CURRENT. See Reverse-current Trip.

TROOSTITE. That structure or constituent in steel known as troostite is indicative of a tempered steel. When steel is fully hardened it consists of martensite, but as it is heated for tempering, troostite begins to form at about 400 degrees and increases with the temperature until the troostite begins to change into sorbite at a temperature of about 750 degrees. See Steels.

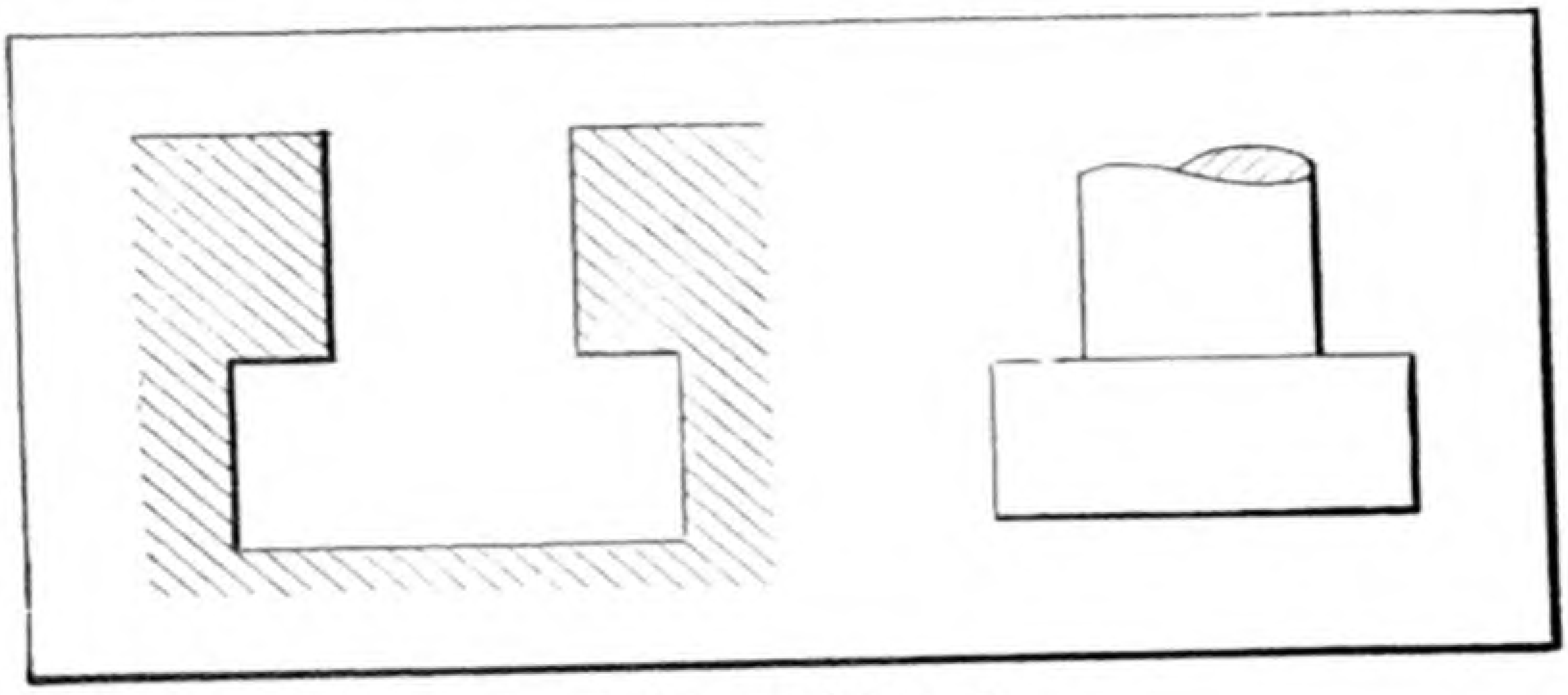
TROPENAS PROCESS. This is a method similar to the Bessemer process, used for the production of light castings in the steel foundry. Small converters are used and a considerable amount of molten ferrosilicon is added to the charge near the end of the "blow."

TROUGH CONVERTER. A trough converter is used in the refining of copper by a method similar to the Bessemer process for converting pig iron into steel. The trough converter is also known as Leghorn and Bisbee converter, and consists of a drum resting on four wheels placed on a stand so that the drum can easily be rotated on its axis. This method, when applied to copper, is generally known as the Manhès process.

TROY WEIGHT. The troy weight is used for weighing gold and silver. 1 pound = 12 ounces = 5760 grains; 1 ounce = 20 pennyweights = 480 grains; 1 pennyweight = 24 grains; 1 carat (used in weighing diamonds) = 3.168 grains; 1 grain troy = 1 grain avoirdupois = 1 grain apothecaries' weight.

T-SLOT. T-slots of the cross-sectional shape shown at the left in the illustration are formed in the tables and bedplates of different types of machine tools to receive the T-bolts used to hold either the work or a fixture

in position during the machining operation. As there has been a certain amount of variation in T-slot and T-bolt sizes, the American standard has been approved by the American Engineering Standards Committee, the National Machine Tool Builders' Association, and the American Society of Mechanical Engineers. This standard covers T-bolts and slots for bolt



T-slot and T-bolt

diameters ranging from $\frac{1}{4}$ inch up to $1\frac{1}{2}$ inches, inclusive, and tables giving the dimensions of American standard T-slots, T-bolts, T-nuts, and T-slot cutters will be found in MACHINERY'S HANDBOOK.

T-SLOT CUTTERS. T-slot cutters are a combination of end-mills and side milling cutters. They are generally provided with a solid shank and are used for cutting the T-slots in the tables of machine tools and fixtures.

T-SQUARE. A T-square consists of a thin ruler used as an aid in drawing straight pencil or ink lines, and having secured to it at one end a head, normally set at right angles to it, and adapted to be held against the edge of the drawing board with the left hand. T-squares are made in two forms: Those with a fixed head and those with a swivel or pivoted head which may be secured in any desired angular position by a thumb-nut, in order to draw lines that are not perpendicular to the guiding edge of the drawing board.

TS'UN. This is a Chinese length measure, legalized in 1908, equal to 3.2 centimeters, or 1.26 inch.

TUBE BENDING. See Pipe Bending.

TUBE EXPANDING. Plain boiler tubes or flues are made to fit tightly into the holes in the tube sheet by expanding the ends. This tightening of the tube is done by simply stretching the metal outward against the hole in the tube sheet, by means of a tool called a *tube expander*. There are two general types of these tools — the sectional expander and the roller expander. The sectional type is composed of a number of steel segments which are held together either by a steel band or a ring of rubber; these segments surround a central tapering mandrel which is driven inward in order to force the seg-

ments outward, thus stretching the tube. The outer surfaces of the segments are usually so shaped that the tube is not only expanded against the wall of the hole through the tube sheet, but enlarged on both sides of the tube sheet. This beading of the tube makes the latter serve as a brace against either tensional or compressive stresses. When tubes are expanded by means of these sectional expanders, this is frequently referred to as the *Prosser method.* The roller type of tube expander has a set of three or more rolls which are mounted in a suitable frame or holder. These rolls bear against a central tapering mandrel which is rotated and, at the same time, forced inward, thus causing the rolls to revolve and gradually expand the tube tightly against the hole in the tube plate. This is frequently called the *Dudgeon method.* The rotation of the mandrel may be effected either by hand or by power.

TUBES, COLLAPSIBLE. See Collapsible Tubes.

TUBE SHEET. The plate or sheet in a steam boiler in which the boiler tubes are held, and in which they are expanded, is called the tube sheet.

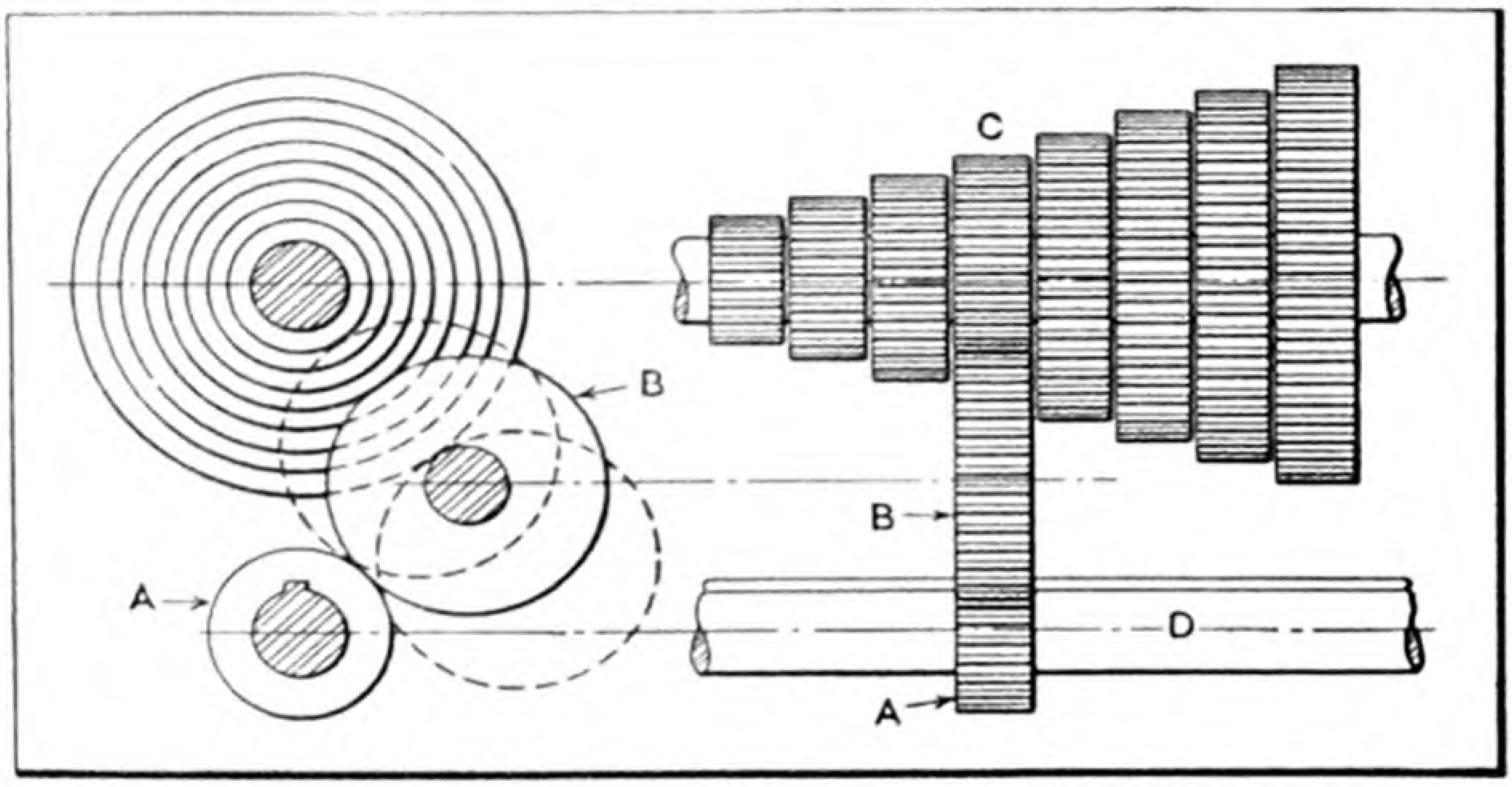
TUBING GAGES. See Gages for Tubing.

TUBING, SEAMLESS. See Seamless Brass and Copper Tubing; also Seamless Steel Tubing.

TUMBLER FILES. These files are of double oval section but are narrower than crossing files, and the surfaces have smaller radii. They are made in either taper or blunt forms and the teeth are double-cut, bastard, second-cut, or smooth. The tumbler file is not used very generally.

TUMBLER GEAR AND CONE. The type of geared feed-changing mechanism illustrated by the diagram, or some modification of it, is often found on engine lathes for varying the feed necessary for turning, and the speed of the lead-screw for thread cutting. In this particular case, there are eight gears in the form of a cone, which progressively vary in diameter, and, in conjunction with this cone of gears, there is a single gear which may be shifted both radially and axially in order to place it into mesh with any gear of the cone. The exact method of mounting this " tumbler gear " varies. With the arrangement indicated by the diagram, there is a splined shaft *D* upon which pinion *A* is free to slide. The tumbler gear *B* (which is merely an idler for connecting pinion *A* with whatever gear of the cone may be selected) is held in position by an arm not shown in the illustration. These two gears, *A* and *B*, remain constantly in mesh, and may be shifted to any position along shaft *D*, for engagement with the various gears of cone *C*. In other designs, instead of having a splined shaft *D*, there is a long pinion extending the length of the gear cone with which the idler gear *B* meshes;

that is, the construction is similar in principle to the arrangement illustrated, with the exception that gear *A* is a long pinion and the idler gear *B* is shifted along this pinion to the required position. Still another method of applying a tumbler gear is to place it upon a splined shaft (corresponding to shaft *D*) which is adjustably mounted, so that engagement with any gear of the cone can readily be made. Power is transmitted directly between this splined shaft and the gear cone, and the shaft itself is adjusted to the required position for bringing the gears into mesh. Whatever the arrangement for



Cone of Gears, and "Tumbler" Gear for Obtaining Speed Variations

transmitting motion between the shaft and the gear cone, it is the general practice to locate and hold the tumbler gear properly in mesh with the different gears of the cone by means of a series of holes or locating surfaces which are engaged by a locking device attached to the tumbler gear frame or shifting arm, in order to hold it in the proper position. Many lathes are provided with this mechanism.

TUMBLING. Tumbling is a process of cleaning, smoothing, brightening, and polishing parts by frictional contact with each other or with some material while the pieces are rotating in tumbling barrels. The tumbling process is also used for a variety of other purposes, such as japanning, painting, and plating metal parts and coloring wood and cork. Tumbling barrels vary in shape, size, and design, but the process in general is the same, although modified according to the type of work and finish desired. Barrel burnishing really comes under the broad definition of tumbling, although the process differs and accomplishes a different result. The usual action of tumbling is to remove or cut away burrs, fins, scale, and flash from parts to obtain a smooth surface or edge. See also Burnishing by Ball Process.

TUMBLING BARRELS. There are two general types of tumbling barrels — oblique tilting and horizontal. They are furnished with steel, cast-iron, cast-brass, and wooden shells, depending on the work to be tumbled. The tilting barrels are used for a greater range of tumbling than the other types. They customarily have a narrow mouth opening, and a wide closed bottom, and may be used for both wet or dry tumbling, but usually not for parts over 6 inches in length. For large or long pieces, or articles having heavy rough surfaces which must be removed by a coarse abrasive, the horizontal type is preferable. Large iron, malleable, steel, aluminum, and brass castings and forgings are ordinarily tumbled in horizontal barrels which have hollow axles, connected to an exhaust fan to draw away the dust. From fifty to one hundred pounds of castings can be tumbled at one time, but only those of a similar character, design, or weight should be tumbled together. For the general run of work, a barrel with a steel shell is preferred, as it withstands hard usage much better than other materials. For wet tumbling, a cast-iron shell is preferable, and for tumbling plated articles or soft metal parts requiring a gentle motion, a wooden shell is preferable. Cast-brass shells are used when pieces are tumbled in acid.

One outstanding advantage of the tilting barrel is that the operator can keep a close watch on the work and take out samples for inspection from time to time, without stopping the machine. The degree of the tumbling action can be made greater or less, that is, more vigorous or more gentle, by changing the angle of tilt. This type of barrel can easily be filled and emptied by tilting the shell either up or down, while the machine is idle or running. If large or long pieces are tumbled in a tilting barrel the parts will show a greater wear at the lower end and tend to become rounded. The amount of roundness depends upon whether the parts are hard or soft, hollow or solid, and upon the angle at which the barrel is tilted.

Plating and Japanning. — For nickel-, brass-, copper- and zinc-plating small articles in quantities, a tilting tumbling barrel equipped with a wood shell and cathode and anode connections may be used, the articles being hung on wires. As the barrel revolves, the work is subjected to a tumbling action which gives it a bright luster. The ease with which the barrel can be loaded and unloaded, and the easy inspection of the work while being plated are advantages of this type of equipment. In japanning small nuts and washers, about two hundred pounds can be dumped at a time into a tilting barrel with about one-half pint of japan and tumbled until the pieces are thoroughly covered and almost dry.

TUMBLING MATERIALS. Many materials are used in tumbling, the medium depending upon the work and the finish desired. The action of the mediums ranges from a mere rubbing to an appreciable grinding. A few

of the mediums are hard-wood sawdust, gravel, pumice, steel slugs, sand, powdered emery, broken emery wheels, ashes, sandstone, rouge, leather scraps and meal, and tumbling jacks and stars. Water or diluted sulphuric acid is sometimes used for tumbling scaly pieces, or preparatory to some rustproofing operation. Such abrasives as emery, sand, and gravel are used both wet and dry, the liquid being either oil, water, or a special solution. After the parts are smoothed, they are often polished by rolling in hard maple sawdust, scrap leather, felt, and talc.

When tumbling operations are done simply to dry and clean parts from oil, grease, and water, sawdust is used and the gentle rubbing also brightens the work. Hinges, keys, and small metal parts, such as stampings and screw machine products, and black and lightly scaled parts, are also cleaned by tumbling with sawdust. Flash and burrs can be removed from brass and steel parts, by using steel slugs and sawdust as the tumbling medium, a suitable proportion being two shovelfuls of sawdust to one of slugs. Flash is sometimes removed by tumbling with white sand, gravel, or emery. Sand can be cleaned from brass castings by the use of brass scrap and water. For smoothing and polishing pawls, studs, and miscellaneous metal work, fine sand and ashes can be used.

When parts are to have fairly clean surfaces and a good bright finish is desired, leather scrap or meal free from tannic acid should be the tumbling medium, and enough so used that a cushion will be formed where the work falls back against the shell of the barrel. Steel balls or similar articles can be polished and finished by placing them in a wooden horizontal or tilting barrel for two operations. The first operation should be one of smoothing by tumbling the parts in a Vienna lime mixture, and the next should consist of tumbling the parts in scrap leather, free from tannic acid. These operations give the parts a high luster or polish without cutting away stock. Sometimes in getting parts ready for plating, when it is only necessary to clean off the grease and oil, hot water and alkali is the tumbling medium.

TUNGSTEN. Tungsten possesses the remarkable quality of giving to steel, when alloyed with it, the characteristic of " red hardness," so that a cutting tool made from a tungsten alloy steel can be used at cutting speeds which heat the tool to a temperature at which carbon tool steels would lose their cutting qualities. Most of the tungsten produced is used as an alloying metal for steel. Tungsten is a very heavy metal, its specific gravity in the pure state being 18.8 (weight per cubic inch, 0.68 pound); in its commercial forms, the specific gravity ranges from 19.3 to 20.2, according to the treatment to which it has been subjected. Tungsten may be obtained in the market either in a compact form or in the form of a powder. Tungsten

requires such a high temperature for melting that it cannot be melted directly into a mass, but, when first obtained from tungsten-bearing ores, it is always in the form of a metallic powder. This powder may be worked into solid masses weighing up to two or three pounds. Tungsten does not oxidize readily, and is practically insoluble in the common acids. Its hardness varies from 4.5 to 8 on the Mohs hardness scale (on this scale, razor steel is rated from 5 to 5.5). It is sometimes harder than quartz, which has a hardness of 7, and may be almost as hard as topaz. Its specific heat is 0.034, and its electrical conductivity (silver = 100) is 14.

TUNGSTENLESS HIGH-SPEED STEEL. See Cobaltcrom Steel.

TUNGSTEN MELTING TEMPERATURE. According to a report on the properties of tungsten, compiled at the Nela Research Laboratory of the General Electric Co., the melting point of tungsten is 3655 degrees C. on the absolute scale, which would be equivalent to about 6125 degrees on the regular Fahrenheit scale. The melting point of tungsten is the highest of any substance known, with the possible exception of carbon. The specific gravity of tungsten is 19.3 at room temperature.

TUNGSTEN STEEL. This steel is largely employed for high-speed metal-cutting tools. The property that tungsten imparts to steel is that of hardening in the air after being heated to a high temperature, and that of "red hardness," or the ability to retain its hardness when the tool is heated by the cutting action to a dull red heat. Tungsten steels usually contain from 5 to 15 per cent of tungsten and from 0.4 to 2 per cent of carbon. In some cases, the percentage of tungsten is as high as 24 per cent. Tungsten steel which contains from 5 to 6 per cent of tungsten and from 0.65 to 0.75 per cent of carbon is used for magnets, because of its great retentivity. Tungsten steel as applied to such tools as threading die chasers, taps, reamers, drills, milling cutters, etc., usually contains about 1 to 1.2 per cent carbon; from 1.2 to 2.5 per cent tungsten; and about 0.30 to 0.40 per cent manganese. Some of these steels also have 0.2 to 0.5 per cent chromium. The tungsten steels known as "fast finishing" usually have 1.1 to 1.3 per cent carbon; 0.20 to 0.35 per cent manganese; 3 to 4 per cent tungsten; and 0.15 to 0.4 per cent chromium.

Wortle Steel. — The special class of tungsten steels known as wortle or cold-drawing die steels, possess unusual resistance to wear and are used in connection with draw-benches for drawing wire and rod. The so-called soft wortle steels usually contain from 1.5 to 3 per cent tungsten; about 2 per cent carbon; and from 0.50 to 0.80 per cent manganese. Such steels are adapted for drawing soft wire, "rounds" and shapes. A hard wortle steel for fine wire drawing contains 11 to 12 per cent tungsten; 1.85 to 1.95

per cent carbon; about 2 per cent manganese, and the same amount of chromium.

TUNGSTEN-CHROMIUM STEEL. This is an alloy steel of the high-speed steel class. Steels for heavy duty usually contain from 16 to 20 per cent tungsten and from 2 to 5 per cent chromium.

TURBINE BLADE STEEL. See under Stainless Steel.

TURBINE, STEAM. A steam turbine is a prime mover in which steam at high velocity impinges upon the blades of a rotating element, thus transforming the kinetic energy of the steam into mechanical energy. The steam turbine, unlike the reciprocating engine, makes use of the *velocity* of the steam instead of its static pressure. The heat energy of the steam is, through expansion, first changed into kinetic energy, and this in turn is transformed into work by the impulse and reaction effects produced by steam jets discharged through suitable nozzles against vanes upon the periphery of a revolving wheel. In both cases, the work done is due to the heat energy contained in the steam. In the reciprocating engine, the action is intermittent, while in the turbine, it is continuous. The steam turbine is especially adapted to central station work for the following reasons: It has a high speed, with close regulation; it gives high economy under variable loads; it works under conditions of practically adiabatic expansion of steam, the ideal condition sought for in the design of all steam engines; it eliminates cylinder condensation, because the passages through which the steam flows are always at practically the same temperature; it has no reciprocating parts, with rubbing surfaces to be lubricated; it produces no vibration which calls for expensive foundations; and finally, the floor space required is much less than for a reciprocating engine of the same power.

Turbines of Reaction Type. — In turbines of the reaction type, the steam is only partially expanded in the nozzle, the expansion being completed after entering the wheel, the steam thus attaining a still higher velocity. In the impulse turbine, the pressure is the same upon both sides of the wheel, while with the reaction type, the steam leaves at a lower pressure than it enters, on account of the expansion which has taken place during its passage through the wheel. For this reason, the buckets or vanes of the reaction turbine differ in form from those of the impulse type, and although commonly known as "buckets," they really act as nozzles. The steam first strikes the vanes in such a manner as to impart a certain pressure by impulse. Its direction is then changed, and it leaves the wheel at such an angle as to react strongly upon the vanes, thus producing in this way the greater part of the power developed.

Impulse Turbines. — The impulse turbine, as its name implies, makes

use of the impulse effect, as far as possible, for the development of power, the heat energy of the steam being first changed into kinetic energy by expansion in diverging nozzles. The rapidly moving particles of steam are then blown directly against the vanes of the turbine wheel, causing it to revolve as an effect of the pressure due to the impulse of the jets. As the expansion of the steam is completed within the nozzle before entering the passages of the wheel, it is evident that the pressure between the vanes is the same as that within the casing in which the wheel revolves, and that the motive force is due entirely to impulse and reaction and not to differences in pressure.

TURBINE, WATER. A water turbine may be of vertical or horizontal design. The horizontal turbine may be provided with a casing and be located in the generating room, or it may be of the submerged type and be located in a basin contiguous to the generating room, with the shaft extending through the dividing wall to the generator. The submerged turbine is used only on very low heads, but in some cases it lends itself to an economical and advantageous design of station. The vertical turbine is particularly well adapted for large units. It takes considerably less floor space and, consequently, smaller foundations than the horizontal type. The manufacturer of water turbines is in the best position to make recommendations as to which type of turbine is most desirable for any particular head and capacity. Sometimes the design of the generator is a determining factor, and the solution of this problem is best solved by the manufacturer of generators.

TURBO-COMPRESSORS. A turbo-compressor is a multi-stage centrifugal compressor, which is built for delivering air from pressures of 5 or 6 pounds up to 120 pounds or more per square inch. In principle, it is like the high-lift turbine pump; the air, upon entering the impeller near the center, is thrown outward by the blades, and its kinetic energy, due to the high velocity, is changed into pressure in fixed diffuser channels, and led back toward the center to the inlet of a second impeller, and so on, the pressure increasing with each stage. An important matter in connection with air compression is that of cooling. For the low pressures of the single-stage compressor, this is not necessary, but for higher pressures, jacket cooling is provided. The turbo-compressor type of machine is particularly well adapted to the removal of heat from the air, because the distance traveled through is much greater than in the cylinder compressor, and the cooling is made continuous by circulating the water through passages between the diffusing chambers of each stage. The advantages of a turbo-blower over other types of blowing engines are the steady flow of air, ease of governing, simplicity of construction, lower first cost, and small space required. On the other hand, gas-engine driven compressors of the piston type are oper-

ated with a by-product which may be had practically free of cost. The turbo-blower, when driven by a direct-connected steam turbine, makes a very compact and efficient unit. When exhaust steam is available from high-pressure engines or turbines, it may be utilized in a low-pressure turbine for driving the compressors.

TURNERS FOR BAR WORK. The tools used on flat turret lathes for turning bar stock are commonly known as "turners." These tools are similar in principle to a box-tool, although, according to the general usage of the terms, there is the following distinction between these two classes of tools: A box-tool is usually understood to be a tool having one or more cutters which, while adjustable, are set in a fixed position relative to the work, whereas the tool of a turner is mounted on a pivoted holder, so that it can be withdrawn readily from the working position for clearing a shoulder or a larger diameter on the work.

TURNER'S SCLEROMETER. With this form of hardness testing apparatus, a weighted diamond point is drawn, once forward and once backward, over the smooth surface of the material to be tested. The hardness number is the weight in grams required to produce a standard scratch. The scratch selected is one which is just visible to the naked eye as a dark line on a bright reflecting surface. It is also the scratch which can just be felt with the edge of a quill when the latter is drawn over the smooth surface at right angles to a series of such scratches produced by regularly increasing weights.

TURNTABLE LATHE. This name is sometimes applied to a turret lathe which has a low circular turret. See Flat Turret Lathe.

TURRET LATHE. The characteristic feature of a turret lathe is the turret which is mounted upon a carriage and contains the tools which are successively brought into the working position by indexing or rotating the turret. In many instances, all the tools required can be held in the turret, although it is often necessary to use other tools, held on a cross-slide, for cutting off the finished part, facing a radial surface, knurling, or for some other operation. After a turret lathe is equipped with the tools needed for machining a certain part, it produces the finished work much more rapidly than would be possible by using an ordinary engine lathe, principally because each tool is carefully set for turning or boring to whatever size is required, and the turret makes it possible to quickly place any tool in the working position. Many turret lathes also have systems of stops or gages for controlling the travel of the turret carriage and cross-slide, in order to regulate the depth of a bored hole, the length of a cylindrical part or its diameter; hence, turning machines of this type are much more efficient

than ordinary lathes for turning duplicate parts, unless the quantity is small, in which case, the advantage of the turret lathe might be much more than offset by the cost of the special tool equipment and the time required for "setting up" the machine.

TURRET LATHE CLASSIFICATION. The names given to turret lathes may either be based upon some prominent constructional feature, or they may be derived from the general nature of the work for which the lathe was primarily designed. All machines which belong to the turret-lathe class are not known as turret lathes, and there is also considerable variation in the names used by manufacturers to designate the different types. Considering first the broad classification of turret lathes, there are the *horizontal* and *vertical* designs; although a very large percentage of the turret lathes in use are of the horizontal design, and those machines which are called *vertical turret lathes* by one manufacturer are classed as *side-head boring mills* by another manufacturer, owing to the fact that they are designed along the lines of a vertical boring mill with the addition of a side head; therefore, the name vertical turret lathe is not one that is applied generally to this type of machine, although such a design may properly be classified as a vertical turret lathe, as it possesses the same general features as a horizontal machine designed for chuck work.

When a machine is simply referred to as a turret lathe, this is generally understood to be a horizontal machine, and it may be designed either for handling bar stock, chuck work, or both for bar and chuck work, and the turret may or may not have a power feeding movement. A turret lathe that is designed more particularly for turning comparatively small screws, pins, etc., from steel rods or bar stock, is commonly (although not invariably) known as a *screw machine*, or as a *turret screw machine*. According to the practice of some manufacturers, the name screw machine is applied to small turret lathes which have a collet chuck in the spindle and a "wire feed" or a mechanism for feeding a wire rod or bar stock through the spindle. When the machine is intended for either bar or chuck work, or for chuck work exclusively, the name turret lathe is commonly used, and such a machine may or may not have a stock-feeding mechanism which operates in conjunction with the spindle chuck. The foregoing method of distinguishing between the two types, however, is not universal, and there is no general agreement in the use of these names.

Turret lathes of the screw-machine class are sometimes given names which indicate rather definitely the type of machine; for instance, the name *hand screw machine* is often applied to turret screw machines in general, in order to distinguish between the hand-operated type and the automatic type, or the term "hand screw machine" may indicate a design not equipped with

an automatic feeding mechanism for the turret slide. The name *wire-feed screw machine* is used by one prominent manufacturer to indicate a design having a mechanism for automatically feeding the stock through the spindle, whereas a machine not having this stock-feeding mechanism is designated as a *plain screw* machine.

Turret lathes are further classified according to the form of the turret. The ordinary turret of the design found on most turret lathes is either hexagonal or round, the former being far more common. The *flat turret lathe* has a turret which is practically a low circular table upon which the tools are clamped, and the name indicates this low, flat design. Lathes of the flat-turret class are sometimes referred to as *turntable lathes*. There is also the *tilted turret lathe*, the turret of which is in an angular position. The *hollow-hexagon turret lathe* is still another machine which derives its name from the form of the turret, although some manufacturers of such lathes do not refer to them as the hollow-hexagon type.

The name in some instances indicates the arrangement of the turret slide. In many cases, the turret only has a longitudinal feeding movement in the direction of the bed; when there is a cross-slide between the turret and the main slide, the name *set-over turret lathe* is used by some manufacturers, but not very generally. The design of the headstock is another feature which is sometimes considered when classifying a turret lathe. Thus there is the *plain-head type* (without back-gears), and the *geared friction-head type* which has back-gears and friction clutches for engaging either the direct cone-pulley drive or the back-gearing. A great many turret lathes are provided with the geared-friction head. Many modern designs are also equipped with geared headstocks and either a single driving pulley or a direct-connected motor drive, instead of a cone-pulley.

The *full-swing side-carriage turret lathe* is a design having a toolpost carriage mounted on the side of the bed, so that it will pass the chuck and enable the turret carriage to be moved up close to the chuck, thus reducing the overhang of the tools to a minimum. A turret lathe that is designed especially for work held in a chuck is often known as a *chucking lathe, chucking machine* or as a *turret chucking lathe*. When a turret lathe has such features as an attachment for chasing threads, and a cross-slide for the turret, it is sometimes known as a *universal turret lathe*, because of the increased range of work for which it is adapted. What is known as a *forming lathe*, or a *forming turret lathe*, is similar to an ordinary design, but usually has a carriage between the turret and the headstock that is arranged for carrying wide-forming tools; in some cases, there is a vertical slide at the rear, so that the forming tool may be fed in a vertical plane. Some forming and chucking lathes have a cross-slide for the turret and the latter carries the forming tools.

Turret lathes which are intended principally for brass work are often referred to as *monitor lathes*, the name "monitor" in this connection indicating a revolving turret. This name is not applied to the same design of turret lathe by different manufacturers, although, in general, it indicates a comparatively small turret lathe which, in many cases, is provided with a thread-chasing attachment of the Fox lathe type and is designed principally for turning, boring, and threading parts made of brass. Some lathes which are listed as the monitor type have a stock-feeding mechanism, whereas others do not have this feature. The turret may or may not have power feed, and some monitor lathes have a cross-feed for the turret, whereas others only have the longitudinal feeding movement.

In England, turret lathes are often called *capstan lathes*. The terms "capstan" and "turret," however, are often used interchangeably, although many firms observe a sharp distinction in their application, in that they apply the name "capstan" only to those machines which have a slide moving in a saddle that is bolted down to the bed, whereas the name "turret" is used when the turret-slide is mounted directly on the bed. The effective difference between the two designs is that the working stroke of the first one is limited by the movement of the turret-slide in the saddle, whereas, with the second arrangement, the longitudinal feeding movement of the turret is limited by the length of the bed.

TURRET LATHE DEVELOPMENT. The invention of a turret for readily and accurately presenting different tools in successive order, seems to have been the work of more than one man. The invention of the vertical turret has often been credited to Henry D. Stone. The turret principle, however, was not originated by Stone as it had been utilized previously by several others, including F. W. Howe and E. K. Root. The first commercial turret lathe, however, seems to have been built by Robbins & Lawrence of Windsor, Vt., in 1854. One of the earliest turret lathes, if not the earliest, was built in 1845 by Stephen Fitch at Middlefield, Conn. The turret of this machine revolved about a horizontal axis and had eight tool positions. A machine built by E. K. Root at the Colt Armory about 1855 and known as a chucking lathe had a horizontal turret. Another early design by Mr. Root had a vertical turret and a stop-screw for the slide but no automatic tripping device. The movements of the turret of the slide were controlled by a lever at the front of the bed opposite the headstock.

TURRET LATHE SIZES. There are two general methods of designating the sizes of turret lathes. If the machine is intended primarily for operating on bar stock which is fed through the spindle, the size of the machine, as listed by manufacturers, indicates approximately, at least, the maximum diameter of stock that will pass through the spindle, and the maximum

length that can be turned. For instance, a 2- by 24-inch turret lathe has a maximum capacity for parts 2 inches in diameter and 24 inches long. In some cases, however, the nominal size of the machine is somewhat less than the actual capacity; thus, a turret lathe listed as a 2-inch size may, in reality, be capable of handling bar stock up to $2\frac{1}{4}$ inches in diameter. The size of a turret lathe intended more especially for chucking operations indicates the maximum diameter that the machine will swing over the ways of the bed; that is, a 24-inch chucking machine is one that will swing parts up to about 24 inches in diameter.

TURRET LATHE SLIDES. Turret-slides for turret lathes may be divided into three general classes: The plain turret-slide, with a longitudinal feeding movement only and a turret that is revolved automatically by the backward movement of the slide; the set-over turret-slide, which has a cross motion that is utilized either for recessing or for radial facing with a single-point tool; and the universal turret-slide, which has longitudinal and cross movements similar to the set-over type, but which has, in addition, an intermediate plate between the cross-slide and the longitudinal slide that may be swiveled to allow the turning or boring of tapering surfaces. The cross-slide is below the swiveling member, so that parts may be faced off square with the spindle when the swiveling slide is set for taper work.

TURRET LATHE STOPS. Practically all turret lathes have some system of stops for regulating the movements of the slides and their tools. Some of the older designs were equipped with a single adjustable stop for all positions of the turret, so that the lengths and positions of the different tools had to be such that all the tools would be properly located when the turret-slide was against the single stop. In order to locate each tool independently, modern turret lathes have multiple stops so arranged that as each tool is indexed to the working position, there is a separate stop which regulates the point at which the forward movement of that particular tool is discontinued. There are several types of these adjustable multiple stops. Some turret lathes have a revolving cylinder which carries a group of adjustable rods, and in other cases there is a bracket on the bed of the machine containing a number of rods capable of adjustment to the various lengths. Still another arrangement comprises a group of bars in the bed of the machine; each bar is adjustable and has a suitable notch in which a plunger may enter in order to arrest the movement of the turret-slide. On some turret lathes, there is an arrangement which provides for the use of supplementary stops, so that several shoulder distances may be obtained for a single position of the turret.

TUYERE OR TWYER. The nozzle through which the blast of air enters a forge or a blast furnace is known either as tuyere or twyer. In blast

furnaces the air passes into the "blast-main" or "horseshoe-main" (a circular pipe nearly surrounding the hearth on the outside), and thence through the twyers into the furnace.

TWIN-ROLLER CHAIN. This is a power transmission chain of the roller type which has in addition to the links connecting the rollers at the ends, a connecting link in the center, the roller being divided into two parts. In an ordinary roller chain, if the roller is too long, the stud upon which it is mounted is liable to bend. In the twin-roller chain, the stud is supported, and more power can be transmitted with a chain of the same pitch.

TWIN-WHEEL GRINDING. Many parts having two or more diameters must be ground. These diameters are sometimes equal, but usually vary. Frequently the logical method of grinding parts with two diameters is to use two wheels spaced according to the location of the surfaces. This combining of cuts has resulted in large increases in production in some plants. The general arrangement of a twin-wheel machine is the same as for ordinary wide-wheel grinding.

TWIST DRILL. The twist drill is used almost universally and is so named because the flutes follow, approximately, a helical path which gives the drill a twisted appearance. Twist drills $\frac{1}{4}$ inch in diameter and larger are made with either straight or taper shanks. The taper of the shank is almost always the Morse standard. In order that the drill may be of sufficient strength to resist the torsional strain to which it is subjected in use, without being at the same time so thick at the point as to require excessive force to make it penetrate the work, it is customary to make the grooves of gradually decreasing depth from the point to the shank. This practice evidently produces a groove which is of less area near the shank, and if no means were employed for increasing this area, there would be a tendency for the chips to clog in the grooves toward the upper end of the drill. In a twist drill with *increased twist*, the lead of the flutes is gradually increased from the point toward the shank. Through the change in angle of the cutter relative to the groove, caused by this change in the rate of the movement, the groove is made wider and its area is thereby increased. In the *constant-angle* drill, the increase of area of the groove towards the shank is obtained by a gradual variation of the angle of the cutter to the axis of the drill, as the groove is milled, the lead remaining constant.

TWISTED SPUR GEARS. When helical gearing is used to connect parallel shafts, the term "twisted spur gear" is sometimes used, because the gearing in this case serves the same general purpose as ordinary straight-tooth spur gearing. This relates to the use of single-helical and not the

double-helical or herringbone gearing. Twisted spur gears are used to connect parallel shafts in order to secure a smoother action than can be obtained with ordinary spur gears. See also Helical Gears.

TYPE METAL. Antimony gives to metals the property of expansion on solidification, and hence, is used in type metal for casting type for the printing trades to insure completely filling the molds. Type metals are generally made with from 5 to 25 per cent of antimony, and with lead and tin sometimes a small percentage of copper as the other alloying metals. The compositions of a number of type metal alloys are as follows (figures given are percentages): Lead, 77.5; tin, 6.5; antimony, 16. Lead, 70; tin, 10; antimony, 18; copper, 2. Lead, 63.2; tin, 12; antimony, 24; copper, 0.8. Lead, 60.5; tin, 14.5; antimony, 24.25; copper, 0.75. Lead, 60; tin, 35; antimony, 5. Lead, 55.5; tin, 40; antimony, 4.5.

A high grade of type metal is composed of lead, 50 per cent; tin, 25 per cent; and antimony, 25 per cent.

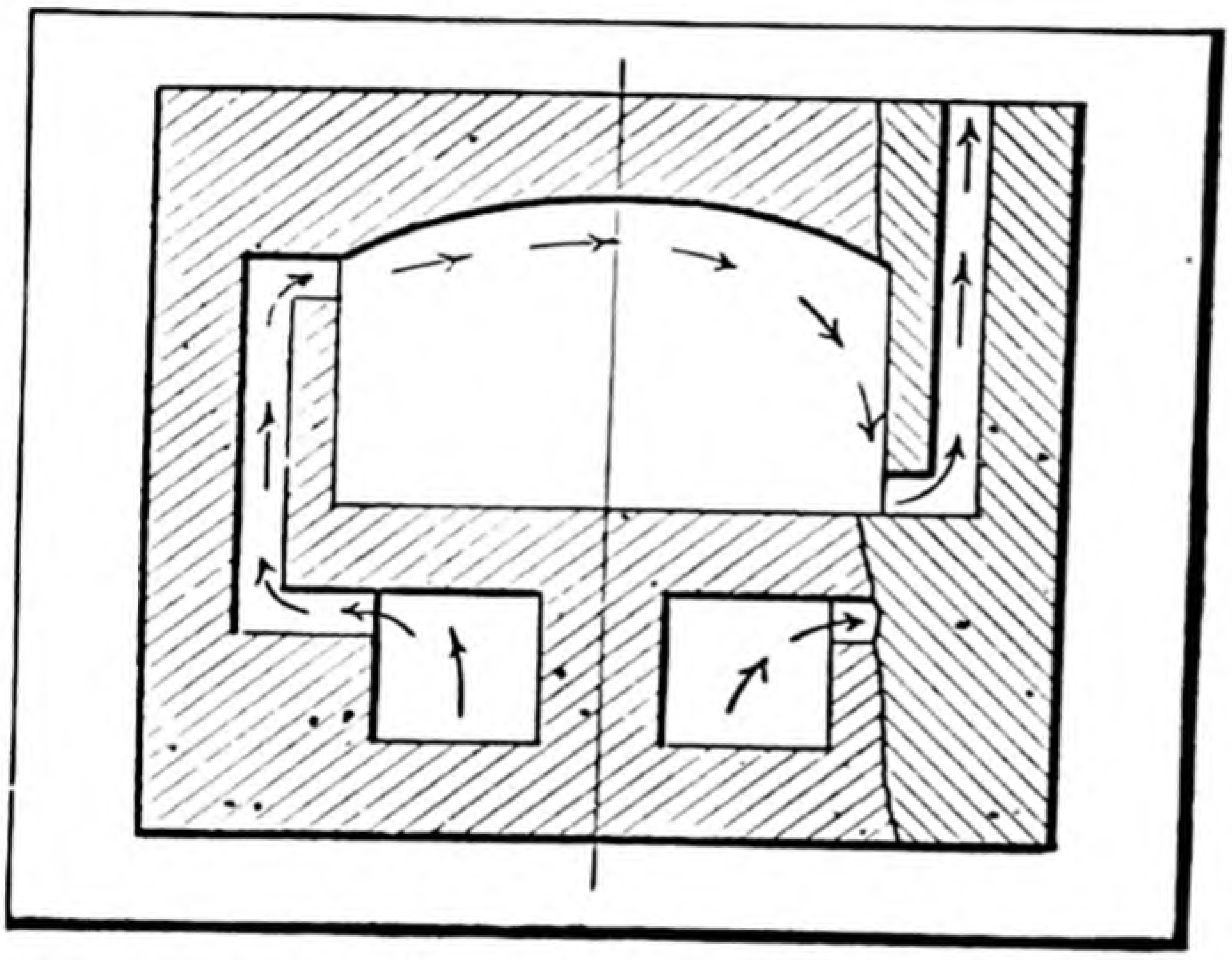
TYPE METAL BEARINGS. Type metal, used for casting type for the printing trades, is sometimes used for light high-speed machine bearings which are not likely to become heated. For bearings, it is used in the form of a lining like babbitt metal. Type metal is a comparatively cheap alloy, because it contains a large percentage of lead and, when cheapness is an important consideration, there is a tendency to use this lining metal instead of the more expensive babbitt alloys containing copper and tin. Type metal bearings should not be used, however, when heavy loads have to be supported by the shaft.

TYPES AND TYPING. Irregular bosses or ends in a drop-forging die that cannot be finished on the die-sinking machine, and that are particularly difficult to chip out, scrape, and riffle to a finish are often formed by typing. A "type" is a punch or small block of steel the end of which is shaped exactly like that part of the forging that is difficult to cut in the die. Types are hardened and drawn to a purple temper. The part of the die that is to be typed is milled and chipped out to as near the outline and depth as is considered safe. The face of the type is then rubbed lightly with Prussian blue, placed in the impression, and, with a piece of copper or brass on its top, the type is struck hard into the impression with a hammer. This operation leaves the high places with a blue facing. These high places are next chipped away, care being taken not to go too deep, and the process is repeated. If properly done, the typed part of the impression will gradually assume the shape of the type and, by striking in the type a number of times, the impressions will take on the smooth finish of the type and be ready for riffling.

U-BOLT. This is a bolt bent to U-form. Both ends of the U are threaded, and such bolts are often used for clamping round parts.

ULTIMATE ANALYSIS. In chemistry, this is a quantitative analysis in which the percentages of all elements contained in the substance are determined.

UNDER-FIRED FURNACES. One of the most common types for small furnaces is the under-fired type. The same principles are sometimes applied to larger furnaces where the firing can be done below the floor line, as in a pit or basement. In heat distribution, this is the most ideal type of furnace. The heat is applied to the portion of the furnace which is the hardest to heat when the application is at the side, end, or top. For high-temperature work, this type has the disadvantage of subjecting the roof of the firebox or combustion chamber to an unusually severe condition, due to the relatively high temperature on top of it as well as underneath. This makes necessary the use of a very refractory material for that portion of the furnace, if the temperature required is high. The heat passages between the combustion chamber and the heating chamber should be of such design that the hot gases will not strike directly against the work. A desirable arrangement is shown by the diagram. With this design, the heating is done largely by conduction through and radiation from the hot walls, instead of by direct contact between the hot gases and the work. Another feature of this type of furnace which demands careful attention, if economy is desired, is the easy loss of heat from the high-temperature gases in their passage upward through the flues in the side walls. This is a very suitable place for the use of heat-insulating brick. If the character of the work to be done will permit the passage of the hot gases directly through the floor of the heating chamber, a greater economy will result by providing the necessary openings therein and omitting the flues in the side walls. Such a design should be used only after a very careful consideration of the resulting effect upon the work. In an under-fired furnace arranged for oil burning,



Diagrammatical Section Showing the Principle of the Under-fired Type of Furnace

the atomized gas from the oil first passes into chambers beneath the heating chamber. The combustion takes place in these lower chambers and the gas then passes through flues into the top of the heating chamber, from which it passes to the outlet flue. The construction of a furnace of this type is simpler than is that of the over-fired type, so that the first cost is less. The cost of repairs is also smaller, but the fuel consumption is slightly greater and it is more difficult to maintain a uniform heat in all parts of the heating chamber than in the case of an over-fired furnace. When built in smaller sizes, however, the heat is easily controlled, and a furnace of this construction is suitable for tool hardening and tempering.

UNDERLOAD TRIP. An underload trip is one that is arranged to trip a circuit breaker when the current flowing through the circuit falls below a certain predetermined amount, the tripping being accomplished by releasing the armature of the magnetic circuit, which, either due to the force of gravity or the energy stored in a spring, forces the armature against the latch thus releasing it.

UNIFLOW STEAM ENGINES. The uniflow type of steam engine is designed to eliminate one of the greatest losses in reciprocating steam engines, namely, initial condensation. With the uniflow engine, the steam enters the cylinder at the end, after passing through steam-jacketed heads. After expansion has taken place, this steam is exhausted through ports located around the center of the cylinder. The steam flows in but one direction, instead of being returned and exhausting at the end of the cylinder where it enters, as with the ordinary type of reciprocating engine; hence the name "uniflow." It is claimed that initial condensation is almost entirely eliminated in the uniflow engine, where the ends are kept hot and the center or exhaust belt cooler. The uniflow engine was not designed originally for non-condensing service, but a design known as the "universal uniflow" is adapted to either condensing or non-condensing operations, economical results being obtained under both conditions.

UNILATERAL TOLERANCES. See under Tolerances.

UNION. The usual trade term for a coupling used to connect pipes. It commonly consists of three pieces which are, first, the thread end fitted with exterior and interior threads; second, the bottom end fitted with interior threads and a small exterior shoulder; and third, the ring which has an inside flange at one end while the other end has an inside thread like that on the exterior of the thread end. Most unions have a gasket which is placed between the thread and bottom ends which are drawn together by the ring. Unions are very extensively used, because they permit of connections with little disturbance of the pipe positions. They are generally

classified under two headings, nut unions and flange unions. Nut unions are ordinarily used for 2-inch sizes and smaller, and flange unions for sizes larger than 2 inches. Nut unions are made of malleable iron, brass and malleable iron and all brass. The all malleable-iron union is the standard malleable union of the trade and requires a gasket. The brass and malleable-iron union (known as the " Kewanee ") requires no gasket and is non-corrosive. The pipe or " thread end " having an external thread upon which the nut or ring screws is made of brass, and the other pipe end (called the bottom) and the nut or ring, are made of malleable iron. When the union is tightened, the harder iron makes a joint in the softer brass. All-brass unions have a circular or conical seat and no gaskets are required. Flange unions are made of cast iron or malleable iron in three weights, standard, extra heavy and hydraulic. A *lip union* is a special form of union characterized by the lip that prevents the gasket from being squeezed into the pipe and obstructing the flow.

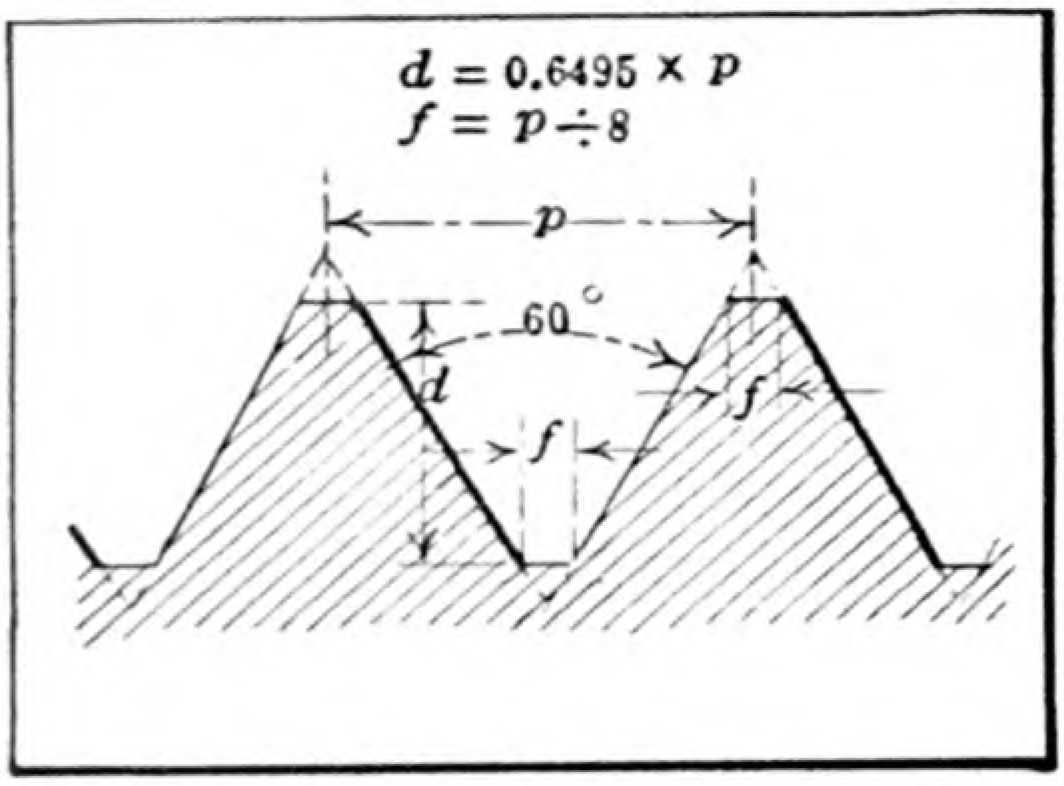
UNI-POLAR MACHINE. A direct-current electrical machine which is the same as an Acyclic Machine.

UNITED STATES STANDARD BOLTS AND NUTS. See Nut Standardization.

UNITED STATES STANDARD FLANGED FITTINGS. In 1912, a standard for flanged fittings was adopted by a committee of the American Society of Mechanical Engineers and the National Association of Master Steam and Hot Water Fitters. This standard was called " The 1912 U. S. Standard for Flanged Fittings," but was never generally adopted because it differed, in some respects, from the dimensions which had quite generally been used in the past by manufacturers of pipe fittings. A compromise standard became effective in 1915, which is known as the " American Standard " and also as " The 1915 U. S. Standard."

UNITED STATES STANDARD SCREW THREAD. William Sellers of Philadelphia, in a paper read before the Franklin Institute in 1864, originally proposed the screw thread system that later became known as the U. S. standard system for screw threads. A report was made to the United States Navy in May, 1868, in which the Sellers system was recommended as a standard for the Navy Department, which accounts for the name of U. S. standard. The American Standard Screw Thread system is a further development of the United States Standard. The thread form which is known as the American (National) form is the same as the United States Standard form but the American Standard system has two series of pitches, one being fine and the other coarse. See American Standard Screw Thread.

Advantages of U. S. Form. — The U. S. standard form has largely replaced the sharp V-thread, because of its superiority. As the U. S. standard has a flat top (see illustration), it is not so easily injured as a sharp V-thread, and taps and dies wear less at the points of the teeth and retain their size longer. Screws having U. S. standard threads are from one-eighth to one-fourth stronger to resist tension than screws with V-threads, because, for a given outside diameter, there is a larger root diameter or effective area. For instance, a U. S. standard screw thread of 1 inch outside diameter and eight threads per inch has a root diameter of 0.8376 inch, whereas a screw of corresponding outside diameter and pitch, but with a sharp V-thread, has a root diameter of 0.7835 inch. The relative strength varies according to the size of the screw, the smaller U. S. standard screws being approximately one-fourth stronger than those having V-threads, whereas the larger sizes are only about one-eighth stronger in tension.



United States Standard Thread

When merely the form of thread but not the number of threads per inch corresponding to a certain diameter, is referred to, the abbreviation U. S. F. (United States form) is employed. The sides of the thread form an angle of 60 degrees with each other. The width of the flat at the top and bottom equals one-eighth of the pitch. If p = pitch of thread, d = depth of thread, and f = width of flat at top and bottom of thread, then:

$$p = \frac{1}{\text{number of threads per inch}}.$$

$$d = \tfrac{3}{4} \times p \times \cos 30 \text{ deg.} = 0.6495\, p = \frac{0.6495}{\text{No. of threads per inch}}.$$

$$f = \frac{p}{8} = \frac{1}{8 \times \text{number of threads per inch}}.$$

UNITED STATES STANDARD SHEET METAL GAGE. A gage system used for commercial iron and steel sheets or plates, including planished, galvanized, tinned, and terne plate. Sheet metal gage tables will be found in MACHINERY'S HANDBOOK.

UNITED STATES STEEL WIRE GAGE. See Steel Wire Gage.

UNIT PLANT. A term used in the appraisal of manufacturing plants to designate a unit portion of the equipment of the plant.

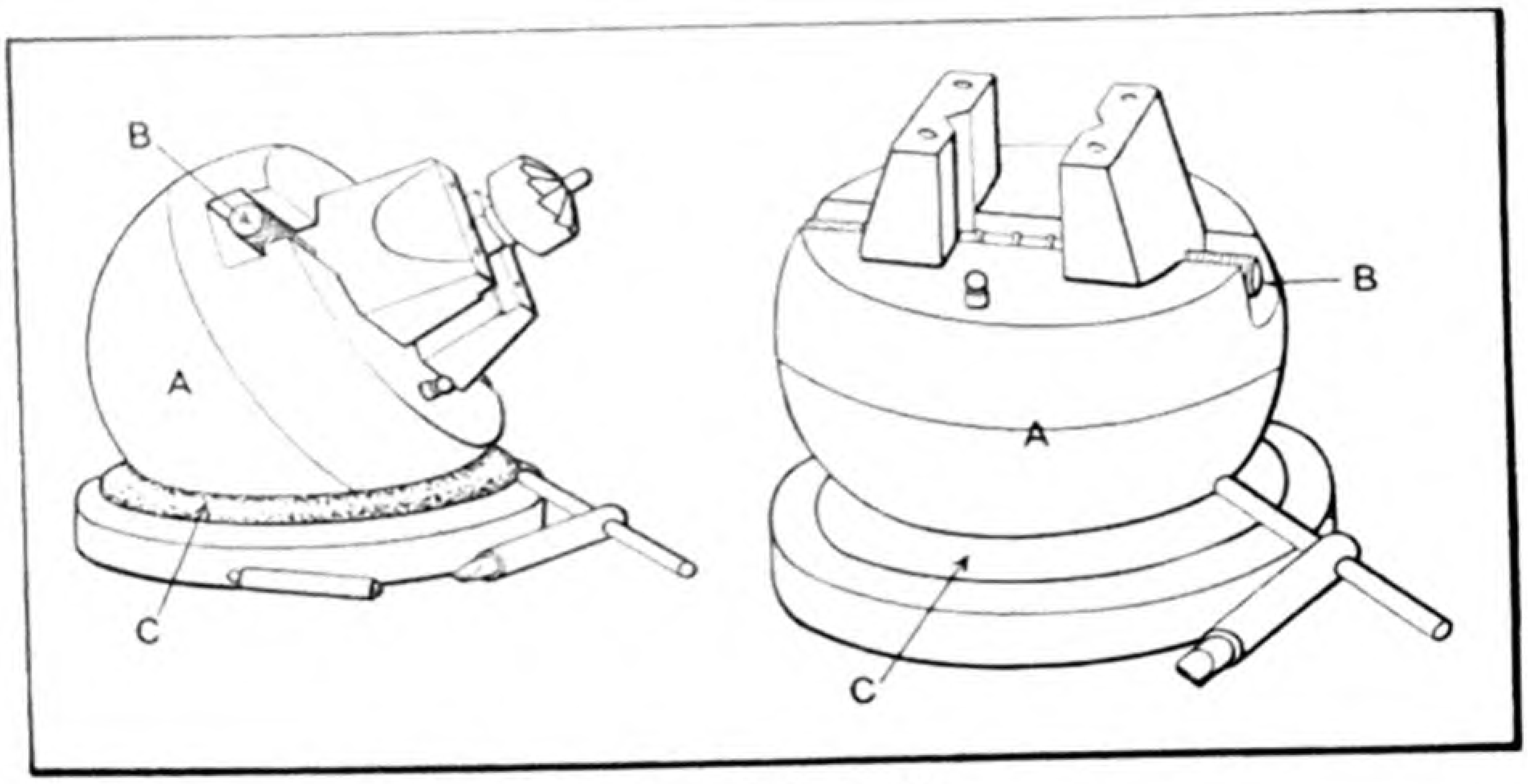
UNIT POLE. In the science of electricity and magnetism, a unit pole is a pole of such strength that, if placed a centimeter away in the air from a like pole, it will repel it with a force of one dyne; or a unit pole is a pole of such strength that, when placed in a magnetic field of one gauss, it is acted upon by a force of one dyne.

UNIT SYSTEM OF MACHINE CONSTRUCTION. The principle of the " unit system " of construction is simply that of dividing a machine into groups of closely related mechanisms, and constructing them with independent frames or boxes in which the shafts, studs, clutches, gears, etc., are assembled. These units of mechanisms are assembled on the main frame to form the complete machine. The natural divisions of the engine lathe, for example, are the headstock, tailstock, carriage, apron, feed-box, change-gear box, etc. These mounted on the bed, require only the lead-screw, feed-rod, and legs to complete the lathe. This system, which has been applied extensively in machine tool design, has several marked advantages: It is the logical development of the interchangeable system of manufacture which has so greatly reduced the cost and improved the quality of manufactured products. The units are made independently in departments suited to the character of the work, by men who, specializing on each particular unit, become experts. The units, being interchangeable, can be replaced by the user when necessary, with a minimum of trouble; they can be removed and returned to the factory for repairs at small expense for freight and handling. The units can be tested independently, and, if defects develop, they are corrected without seriously blocking the output of finished machines. If a complete machine is tested and found faulty, it is held until a minor defect, perhaps, is found and repaired. The same defect found in a separate unit would have been corrected before reaching the assembly floor and thus no delay at this stage would have occurred. An important advantage to the machine tool builder is the ease with which units can be incorporated in various designs. The builder, say, of milling machines, can use the same feed-box in several sizes and styles, and is thus able to produce a variety of designs at a minimum cost for jigs and fixtures, all in harmony with the general design.

UNIT TOOLING. By " unit tooling " is meant the locating of an entire series of tools used for machining a part, in permanent relation to each other. This is accomplished, in the case of a turret lathe, by providing a special arm or multiple tool-holder, which is fastened to the turret. It is evident that the employment of a unit tooling arrangement is a production expedient only when quantities of work of a standard nature are handled. The expense of making such a tool-holder would not be warranted for special classes of work on which no repetition orders are likely to be received.

UNIVALENT. Univalent, also known as monovalent, is a term used in chemistry to designate that an atom of an element (like hydrogen) combines with but one atom of another element.

UNIVERSAL BALL VISE. For small fine work, such as die-sinking, stamp cutting, and mold making, the universal ball vise is in general use. The body *A*, see illustration, is of spherical form and rests in a ring-shaped base *C* having enough frictional resistance to prevent the body from turning under normal working conditions. The jaws are operated by a right- and left-hand screw *B* controlled by a socket wrench. The jaws are also drilled



Universal Ball Vise

at the top to receive pins, so that work can be held between the pins directly on top of the jaws. The illustration at the left shows the vise arranged to hold a small milling cutter while the toolmaker is finishing it. For many purposes connected with fine toolroom work, a vise of this kind is useful.

UNIVERSAL CHUCKS. The universal or concentric type of chuck is extensively used on engine lathes because the simultaneous movement of the chuck jaws makes it possible to quickly grip circular parts so that they are located true or concentric with the lathe spindle. The jaws of a universal chuck all move together and keep the same distance from the center, and they can be adjusted by turning any one of the screws, whereas with the independent type the chuck wrench must be applied to each jaw screw. The *combination chuck* may be changed to operate either as an independent or universal type. The advantage of the universal chuck is that round and other parts of a uniform shape are located in a central position for turning without any adjustment. The independent type is, however, preferable in some respects as it is adapted for holding odd-shaped pieces because each jaw can be set to any required position.

UNIVERSAL DIE-SINKER. See under Die-sinking.

UNIVERSAL JOINT. The universal joint is a form of coupling for connecting two shafts which are so placed that their center lines intersect, but are not in the same straight line. Shafts so located may be connected by a universal joint which will transmit the motion from one to the other. This joint has also been called a " Cardan joint " or a " Hooke's coupling " after the Italian who first described it and the Englishman who first applied it. Its form varies according to the particular application.

UNIVERSAL MILLING MACHINE. The universal milling machine was invented by Joseph R. Brown in 1861. This should not be confused with the so-called universal miller designed by Frederick W. Howe in 1852. The latter machine had certain universal adjustments, such as a chuck that could be indexed and inclined in two planes and a vertically adjustable cutter-slide. The machine designed by Mr. Brown was a universal type according to present-day usage of the term and it was designed for such operations as helical milling, gear cutting, and various jobs requiring either indexing or a combined rotary and axial motion. The first universal machine made by the firm then known as J. R. Brown & Sharpe was sold to the Providence Tool Co. in 1862, and was used in making special tools for the manufacture of United States Government rifles. For information about the mechanical features of universal machines see Milling Machines, Universal Type.

UNIVERSAL MOTOR. A type of electric motor designed to operate on either direct or alternating current. Such motors are often applied to small portable electric drills.

UNIVERSAL RADIAL DRILLING MACHINE. A radial drilling machine of the *plain type* can only be used for drilling holes at right angles to the base. The universal radial drilling machine is adapted to the drilling of holes at various angles with the base. The head and spindle of a " full universal " machine can be set at an angle with the radial arm, and the arm itself can also be rotated about its own horizontal center or axis, so that the drilling spindle can be placed in almost any position.

UNIVERSAL ROLLING MILL. A type of rolling mill much used in the United States for plate making and jobbing work is the " universal mill." This type of mill consists of a pair of ordinary plain cylindrical rolls mounted in the usual way, at the back of which a shorter pair of similar rolls are mounted with their axes in a vertical position, so that they will compress the edges of the bar at the same time that the horizontal rolls compress it on the flat sides. With this arrangement it is unnecessary to turn the ingot over on its side so as to work the edges as is the case with

slabbing rolls. The vertical rolls, which are usually smaller in diameter than the horizontal ones, are generally driven from the upper ends by means of miter gearing connecting with a shaft that crosses the tops of the housings. Originally, the vertical rolls were driven from the bottom ends, but scale from the steel being rolled fell into the gearing and caused the teeth to wear out so rapidly that they are now driven from the top. By the combination of four rolls any width and thickness of flat plates within the range of the mill can be rolled with equal facility. It is customary to straighten the edges of the plates that are rolled in these mills by pressing them while they are hot between two bars which are squeezed against the plates laterally.

UNIVERSAL SHAPERS. When a shaper has a work-table which can be swiveled about an axis that is parallel to the line of motion, and has an auxiliary tilting side, which has angular adjustment with reference to the axis about which the main table swivels, it is sometimes known as a *universal* shaper. A shaper designed in this way is especially adapted for tool and die work, owing to the universal adjustment. The range of such a machine may be still further increased by means of extra attachments.

UNIVERSAL TURRET LATHE. When a turret lathe has such features as an attachment for chasing threads, and a cross-slide for the turret, it is sometimes known as a *universal turret lathe*, because of the increased range of work for which it is adapted.

UNLOADER. In air compressors, an unloader is a pressure regulator which closes the inlet pipe of an air compressor and connects the two ends of the air cylinder, when the receiver pressure reaches the maximum point desired.

UPRIGHT DRILLING MACHINE. See Drilling Machines.

URANIUM. Uranium is a white malleable metal which is fairly hard although softer than steel. Its specific gravity is 18.7, and its specific heat, 0.0276. It melts at a temperature of 2400 degrees C. (4350 degrees F.). It tarnishes very slowly in the air. Uranium is chemically related to chromium, molybdenum, and tungsten. It is claimed that uranium in high-speed steels increases the cutting efficiency and durability to a marked degree.

VACUUM BREAKERS. The function of a vacuum breaker is to destroy the vacuum in a steam condenser and protect the engine or turbine from possible flooding, if the condenser should fill with water. The vacuum breaker ordinarily consists of a ball float, placed either in the condenser proper or in an adjoining and communicating chamber, and which, upon flooding of the condenser, will operate a valve and allow air to enter the condenser chamber or the adjacent exhaust steam line. The valve may be operated either directly by a float or through the medium of a steam-actuated piston controlled by the float and a lever. Other types of vacuum breakers which are not as common consist of electrically or mechanically operated valves placed in the line between the engine and the condenser or directly on the condenser. These valves are used in connection with an engine stop system, and while employed primarily for the purpose of preventing overspeeding of the engine, under certain conditions they act as effectively as the other type of vacuum breakers. A vacuum breaker should not be confused with an atmospheric relief valve which is placed in the exhaust line between the engine or turbine and the condenser, to provide a means of escape for the steam, with a minimum back pressure, when the condenser becomes inoperative.

VACUUM CHUCKS. For holding pieces made of various magnetic and non-magnetic materials on grinding and milling machines, shapers, planers, lathes, etc., vacuum chucks are used in essentially the same manner as magnetic chucks are employed for holding pieces made of iron or steel. The upper surface of a vacuum chuck consists of a flat plate perforated with small holes leading to an inside chamber which is coupled up to an exhaust tank. The high vacuum in this tank is maintained by means of a vacuum pump. Each chuck is supplied with a control valve, and as a result, the vacuum chuck is controlled by manipulating a valve in the same way as the magnetic chuck is operated by an electric switch.

VACUUM IN CONDENSER. The vacuum attainable in a condenser is dependent on the temperature of the circulating water available. The average temperature of the water for a period of four or six weeks during the hot season might be taken as the governing temperature for determining the vacuum to be maintained; then, with colder water, the vacuum will improve. For preliminary considerations, the highest vacuum that may be expected ranges from about 27 inches for a circulating water temperature of 95 degrees F. to 29 inches for a water temperature of 60 degrees F. A condensing turbine will have a steam consumption of about one-half that of a non-condensing turbine, and the power consumption of the condenser auxiliaries will be approximately 5 per cent of the steam supplied to the

condensing turbines. The initial cost of the condensing equipment is more than offset by the cost of the additional boilers required for the larger steam production to supply non-condensing turbines.

VACUUM PUMP. See Air or Vacuum Pump.

VACUUM PUMP, HYDRAULIC. See Hydraulic Vacuum Pump.

VACUUM SEPARATOR. This is a device used for removing oil from the water of condensation in a steam plant, so that the water may be returned to the boilers.

VALENCE. The power of an atom to hold other atoms in combination with it is known as *valence*. This term, however, refers only to the number of atoms with which an atom may combine, and not to the firmness with which they are held. The atoms of most elements combine with from one to four other atoms, but the atoms of some elements combine with from five to seven atoms. The valence of an element is usually represented by means of dashes, but sometimes a small Roman numeral is placed at the right of, and above, the symbol. When the atoms of an element (like hydrogen) combine with but one other atom, the element is said to be "univalent" or "monovalent;" it is also said to have one bond. This valence is shown by placing one dash after the symbol; for example, hydrogen would be written H –. When the atoms combine with two other atoms, the element is said to be "divalent" or "bivalent;" it is also said to have two bonds. This valency is shown by placing a dash before and after the symbol; for example, sulphur will be written – S –. In like manner, an element may be a trivalent, a quadrivalent or tetravalent, a quinquivalent or pentavalent, a sexivalent or hexavalent, or a septivalent, according as its atoms combine with three, four, five, six, or seven univalent atoms. The valency of an element, however, is not constant; it varies with the conditions, especially with the temperature and the character of the element with which a given element combines. As a rule, the valency decreases as the temperature increases.

VALVE. Valves are used in regulating the flow of liquids or gases which pass through them, and are either controlled by hand or operated by suitable application of power. Valves which are incorporated in the design of engines or other forms of mechanism, such as locomotive slide valves, pump valves, etc., represent forms designed for a specific purpose as compared with the types used in water pipes, steam pipes, etc. Of the many types of valves in use, hand-operated valves which control the supply of steam or water in pipes are the most common. One of two forms is generally used for these purposes, *viz.*, either the globe or gate valve. In the control of

steam, the globe valve in some form is common, while in pipe lines for water or other liquid, the gate valve is extensively used.

VALVE, BALANCED. In order to assist in the operation of valves that are under heavy pressure, provision is made in certain types of valves called "balanced valves," to equalize the pressure on each side of the valve and thus make the operation easier. Automatic valves also are designed to work on a similar principle, the valve being operated by any change in pressure of the liquid or gas passing through it. A valve of the automatic type is often used for automatically closing a pipe line when an abnormal flow of steam occurs at any portion of the line. Valves of this kind may be placed between each boiler in a battery and the steam header. In the event that a steam main should burst or a cylinder head fly off, or if an injury should occur to the steam line beyond the valve, all the valves of the different boilers in the battery would close immediately and prevent the steam from escaping into the building and doing further damage. In the case of an accident to a single boiler in a battery, such as a burst tube, the valve on that particular boiler would instantly close and prevent all the other boilers connected to the header from emptying their steam through the opening in the injured boiler.

VALVE BRONZE. This is an alloy composed mainly of copper, tin, and zinc, containing, according to the U. S. Navy specifications, approximately 87 per cent of copper, 7 per cent of tin, 5 per cent of zinc, with a maximum of 0.06 per cent of iron and 1 per cent of lead.

VALVE, BY-PASS. See By-pass Valves.

VALVE DIAGRAMS. In designing a slide valve for a steam engine and the mechanism that operates the valve, it is desirable to be able to determine readily the position of the valve relative to the steam ports, for any given position of the crank or piston. What are known as "valve diagrams" are commonly used for this purpose. These diagrams not only show graphically the relative positions of the valve and crank, but also make it possible to design a valve with reference to a predetermined form of indicator card. Valve diagrams also indicate the effects of changes in the design of the valve on the steam distribution. In connection with steam engine work, certain problems or quantities relating to the point of cut-off, lead, etc., are assumed, and the remaining ones are required and may be determined by means of the valve diagrams. For instance, a designer might be given the point of cut-off, point of release, the lead, and the maximum port opening, the problem being to determine the valve travel, the outside and inside lap, and the angle of advance. By means of a suitable diagram, the valve travel, lap, etc., corresponding to these specified quantities may be readily determined.

There are several different forms of valve diagrams, the Zeuner and the Bilgram diagrams being commonly used.

VALVE, GATE. See Gate Valves.

VALVE GRINDING. When the joint between a valve and its seat is formed by a metal-to-metal contact, grinding is commonly resorted to, in order to secure a joint that will not leak when subjected to the pressure of a gas or fluid. The grinding is done by applying some kind of an abrasive between the surfaces of the valve and seat, and the valve is turned in first one direction and then the other, so that any slight imperfection or lack of fit between the valve and its seat will be corrected by the action of the abrasive. When a great many valves have to be ground, they are often turned, while grinding, by machines designed especially for this work. Such machines are often arranged so that several valves may be ground simultaneously. The spindles do not revolve continuously in one direction, but reverse, say, every $1\frac{1}{4}$ revolution and a cam raises and lowers the spindles at intervals of, say, 20 revolutions, to allow the abrasive or grinding compound to enter the valve-seats.

VALVE MOTIONS, DIRECT AND INDIRECT. When the eccentric of a steam engine is so connected with the valve that the center of the eccentric and the valve both move in the same general direction, the motion is said to be *direct*. On the other hand, when there is an intervening rocker arm which reverses the movement and causes the valve to move backward, while the center of the eccentric is moving forward, the motion is said to be *indirect*.

VALVE SETTING. The adjustment of the valve-operating mechanism on steam engines, for obtaining the correct movement of the valve relative to the piston, so that the steam will be admitted to and exhausted from the cylinder at the right time, is known as *valve setting*. The exact method of setting steam engine valves depends upon the type of engine and design of the valve-operating mechanism. In general, the setting of a simple slide valve operated by an eccentric involves two operations: First, the rods which impart motion from the eccentric to the valve should be adjusted so that the valve movement will be equal each way from the central position over the steam ports; second, the eccentric should be so located with reference to the main engine crankpin that the valve opens and closes the ports at the correct time with reference to the movement of the piston. If the connection between the eccentric and valve rod is *direct* and not through a reversing rocker arm, the eccentric is always in advance of the crank, as determined by the direction of rotation; hence, the crank will follow the eccentric, and the angle between the eccentric and crank will equal 90 de-

grees plus a slight additional movement necessary, owing to the lap of the valve and the amount of "lead" or initial port opening desired. When a reversing rocker arm is between the eccentric rod and valve rod, the eccentric must be placed *back* of the crank an amount equal to 90 degrees minus a slight amount due to the lap of the valve. In this case, the crank will lead when the engine is in motion.

VALVE-SETTING MACHINE. In connection with locomotive valve setting, it is necessary repeatedly to place the main driving wheels at the dead-center positions. There are three general methods of securing the necessary motion of the driving wheels for setting valves. The old method was to move the entire locomotive along the track by means of pinch-bars; obviously, this was a slow laborious method. An improved method is to turn only the main driving wheels, which are simply connected with the cross-heads by the main rods (the side-rods being disconnected), and are mounted on rollers which are rotated either by a hand-ratchet lever or by an air motor. There are two rollers under each wheel, and a supporting frame for the rollers, so that the rollers and driving wheels may be readily rotated. This device is sometimes known as a "valve-setting machine."

VALVE STEEL, POPPET. See under Stainless Steel.

VALVE TRAVEL. The total distance that an engine slide valve moves in one direction is known as the *travel*. This term is used instead of the word "stroke," which might properly be applied.

VANADIUM. Vanadium is a light colored metal having a specific gravity of from 5.5 to 6. It melts at a temperature of 1750 degrees C. (3182 degrees F.). Its specific heat at 32 degrees F. is 0.124, and its electrical conductivity (silver = 100) is about 5; it is non-magnetic. Vanadium is widely distributed in small quantities in a large number of minerals. It is an important alloying metal used in steel, vanadium steel having a number of valuable properties which are not obtainable in ordinary steel. On account of its great affinity for carbon, oxygen, and nitrogen at high temperatures, absolutely pure vanadium has not been produced. Owing to its very high melting point, vanadium, even if it were commercially possible to produce it reasonably pure in the metallic state, would present much difficulty in alloying with other metals. Fortunately, it is relatively easy to reduce vanadium as an alloy of iron, ferro-vanadium, containing approximately one part of vanadium and two parts of iron. This alloy has a melting point of about 1300 degrees C. (about 2370 degrees F.), which is low enough for it to melt and alloy readily when added to molten steel.

VANADIUM STEEL. The two most marked characteristics of vanadium steel are its high tensile strength and its high elastic limit. Another equally

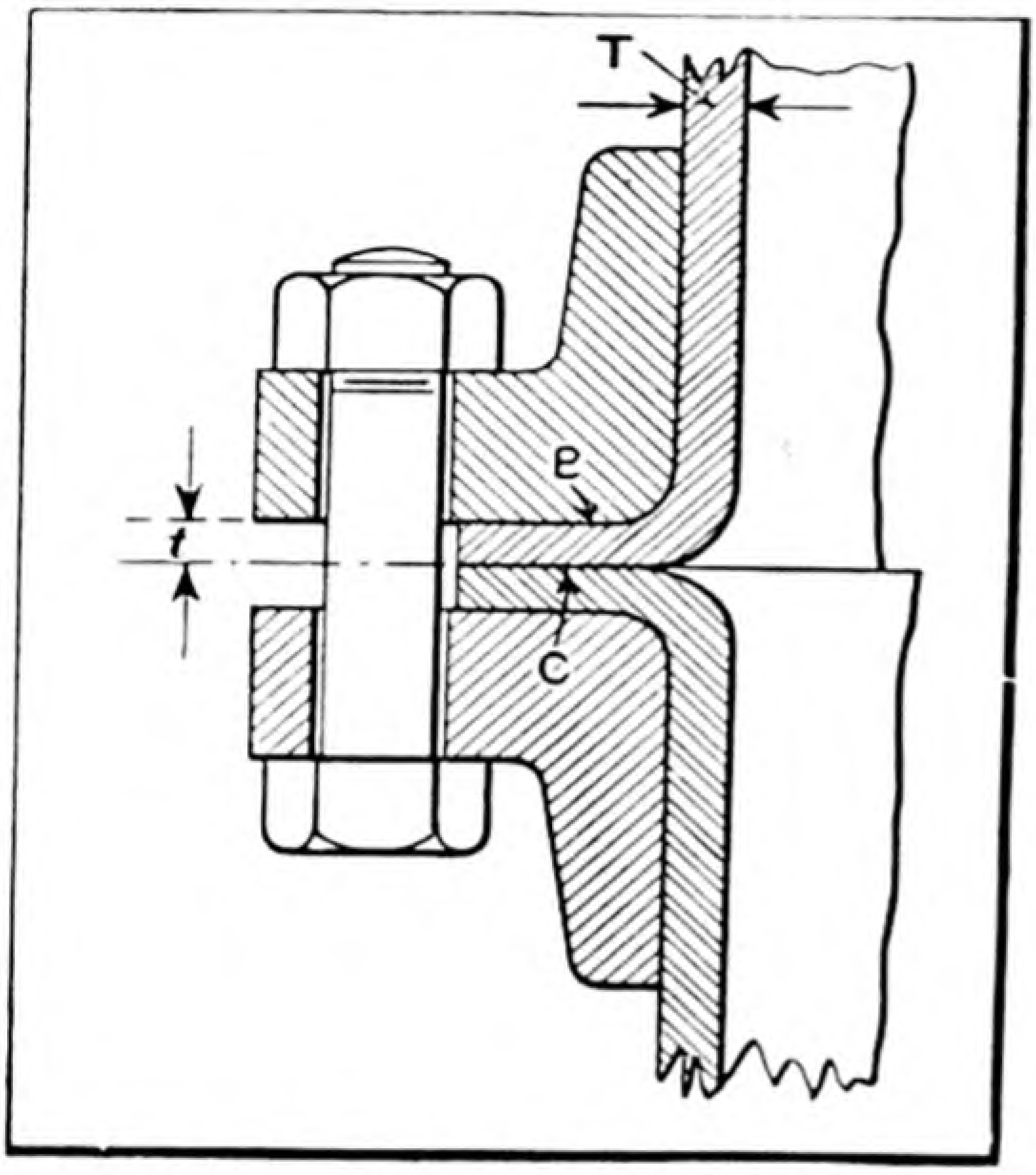
important characteristic is its great resistance to shocks; vanadium steel is essentially a non-fatigue metal, and, therefore, does not become crystallized and break under repeated shocks like other steels. Tests of the various spring steels show that, when subjected to successive shocks for a considerable length of time, a crucible carbon-steel spring was broken by 125,000 alternations of the testing machine, while a chrome-vanadium steel spring withstood 5,000,000 alternations, remaining unbroken. Another characteristic of vanadium steel is its great ductility. Highly-tempered vanadium-steel springs may be bent sharply, in the cold state, to an angle of 90 degrees or more, and even straightened again, cold, without a sign of fracture; vanadium-steel shafts and axles may be twisted around several complete turns, in the cold state, without fracture. This property, combined with its great tensile strength, makes vanadium steel highly desirable for this class of work, as well as for gears which are subjected to heavy strains or shocks upon the teeth. Chromium gives to steel a brittle hardness which makes it very difficult to forge, machine, or work, but vanadium, when added to chrome-steel, reduces this brittle hardness to such an extent that it can be machined as readily as an 0.40-per-cent carbon steel, and it forges much more easily. Vanadium steels ordinarily contain from 0.16 to 0.25 per cent of vanadium. Steels of this composition are especially adapted for springs, car axles, gears subjected to severe service, and for all parts which must withstand constant vibration and varying stresses. Vanadium steels containing chromium are used for many automobile parts, particularly springs, axles, driving-shafts, and gears.

VANDYKE PRINTS. Vandyke negatives have white lines on a brown background. If positive prints are desired or those having either blue or brown lines on a white background, they may be obtained in the following manner: The original tracing is first used to make a negative copy on thin vandyke paper. This copy will have white transparent lines on an opaque dark brown background. Another print is then made by using this vandyke negative in place of the original tracing, and the result is a positive print which will have dark lines on a white background if vandyke paper is used, or blue lines on a white background if regular blueprint paper is used. Similar results may also be obtained on cloth by using either prepared blueprint cloth or vandyke cloth, depending upon whether a blue-line or a brown-line print is desired.

VANISHING THREAD JOINT. A vanishing thread joint is a pipe joint made up of a tapered pipe thread screwed into a tapered thread socket. The taper of the thread is the standard pipe thread taper of $\frac{3}{4}$ inch to the foot; the only difference lies in the fact that the thread is carried to the vanishing point instead of ending abruptly as is the case with commercial

pipe threads. It is used for signal pipe and rotary drill pipe which require high tensile and torsional strength.

VAN STONE OR ROLLED JOINT. The original form of Van Stone pipe joint, commonly referred to as a *rolled joint*, due to the fact that the pipe is rolled or lapped over the face of the flange is shown by the illustration. In making this and similar types of rolled joints, the flange is bored out to fit loosely over the end of the pipe, after which the pipe end is heated in a furnace to the required temperature and then lapped or rolled over the face of the flange as shown at *B*, the outer edge of the lapped portion of the pipe coming just inside of the bolt holes, as indicated. The rolling or lapping of the pipe is accomplished by the use of special machinery designed especially for that purpose. In making Van Stone joints in a steam main, any good metallic or vulcanized gasket suitable for high-pressure superheated steam may be used. Flanges for rolled joints can be made of cast iron, cast steel, or forged steel, depending upon the service for which the joints are intended. Rolled or forged steel flanges should always be given the preference over cast iron or cast steel for high-pressure service and where superheated steam is to be conveyed. Cast-iron flanges should not be used on steam mains for pressures above 150 pounds per square inch.



Van Stone or Rolled Joint

VAPOR. This term is often used to designate gases in general, but it is usually restricted to the gaseous form of substances that at ordinary temperatures and pressures are liquids or solids.

VAPOR LAMPS. To this class of lamps belong the mercury-vapor lamps and the Moore tube. In the mercury-vapor arc lamps, the arc is formed in an evacuated tube, mercury being used for one and sometimes for both electrodes. The light is given off by luminescence of the mercury vapor in the arc stream, the electrodes contributing no light at all. The length of the arc varies from 1.25 to 50 inches, depending upon the vapor pressure, candlepower, and voltage for which the lamp is designed. The light from mercury tubes has a bluish-green color, and is characterized by an entire absence of red light rays. The high actinic quality of the rays makes it a very efficient lamp for photographic work, and it is also useful in revealing detail. The Moore tube lamp consists of a glass tube filled with a rarefied

gas through which an electric discharge takes place. The color of the light and the efficiency depend upon the kind of gas used and upon the pressure in the tube.

VARIANCE. This term is used to represent the amount by which the readings of an instrument vary in successive indications of the same value of the measured quantity. Variance may be due to lost motion; friction; changes due to the stress-strain relation of springs in the force-resisting or restoring element of the instrument; changes in the distribution of parts, as variation of position of pins in bearings or variation in the amount of liquid retained on wetted surfaces. There may also be other factors of less importance.

VARNISH. Varnish is a liquid consisting of a gum or resin dissolved either in alcohol, in which case it is known as *spirit* varnish, or in oil, when it is known as *oil* varnish. Varnish is used in the mechanical trades in pattern-making, and also for covering metal parts. Patterns intended for repeated use are varnished to protect them against moisture, especially when in damp molding sand. The varnish most generally used is the yellow shellac varnish which is made by dissolving gum shellac in grain alcohol. Wood alcohol may also be used for this purpose, but produces an inferior varnish. Varnishes may be given color by the addition of various coloring agents. The following compositions of varnishes for covering metals are recommended: Fine orange shellac, 21 parts; methylated spirit, 79 parts. The specific gravity of this varnish is about 0.885. Another varnish consists of fine orange shellac, 8 parts; seedlac, 4 parts; turmeric, 29 parts; methylated spirit, 59 parts. The specific gravity of this varnish is about 0.865. A lacquer or varnish also used is made from seedlac, 11 parts; turmeric, 5 parts; methylated spirit, 84 parts. The specific gravity of this lacquer is 0.85.

VARNISH, PATTERN. See Pattern Varnish or Shellac.

VECTOR. See Sine Wave.

VEDRO. This is a Russian measure of capacity for liquids, equal to 12.3 liters or 3.25 U. S. gallons.

VEGETABLE GLUE. See Glues for Wood.

VELOCITY. Velocity is distance divided by time or the rate of motion in a unit of time, and is expressed in feet per second, feet per minute, miles per hour, etc. Velocity may be either *absolute* or *relative.* The absolute velocity of a body is its velocity with reference to some object which is considered completely at rest; the relative velocity of a body is its rate of motion with relation to another moving body. In considering velocity in

practical mechanics, the earth is assumed to be stationary, so that the velocity of any moving body, as, for example, a moving train with relation to the rails, would be absolute velocity, but a person walking through the train would move with a certain relative velocity with reference to the train, and with an absolute velocity with reference to the road-bed over which the train moves. If two trains moving in opposite directions, at a speed of 50 miles an hour, pass each other, they have each an absolute velocity of 50 miles an hour, but the relative velocity between the two trains would be 100 miles. If two trains, one of which has a speed of 40 miles an hour and the other 25 miles an hour, move in the same direction, and the faster train passes the slower, the relative velocity of the faster train with reference to the slower will be 15 miles an hour, but its absolute velocity is 40 miles an hour.

VELOCITY HEAD. Velocity head is the force, causing a gas or liquid to flow through a pipe line, which is due to the velocity of the gas or liquid.

VELOCITY PRESSURE. Velocity pressure is the working pressure which actually forces a fluid or gas through a discharge opening and which equals the difference between the dynamic pressure and the static pressure.

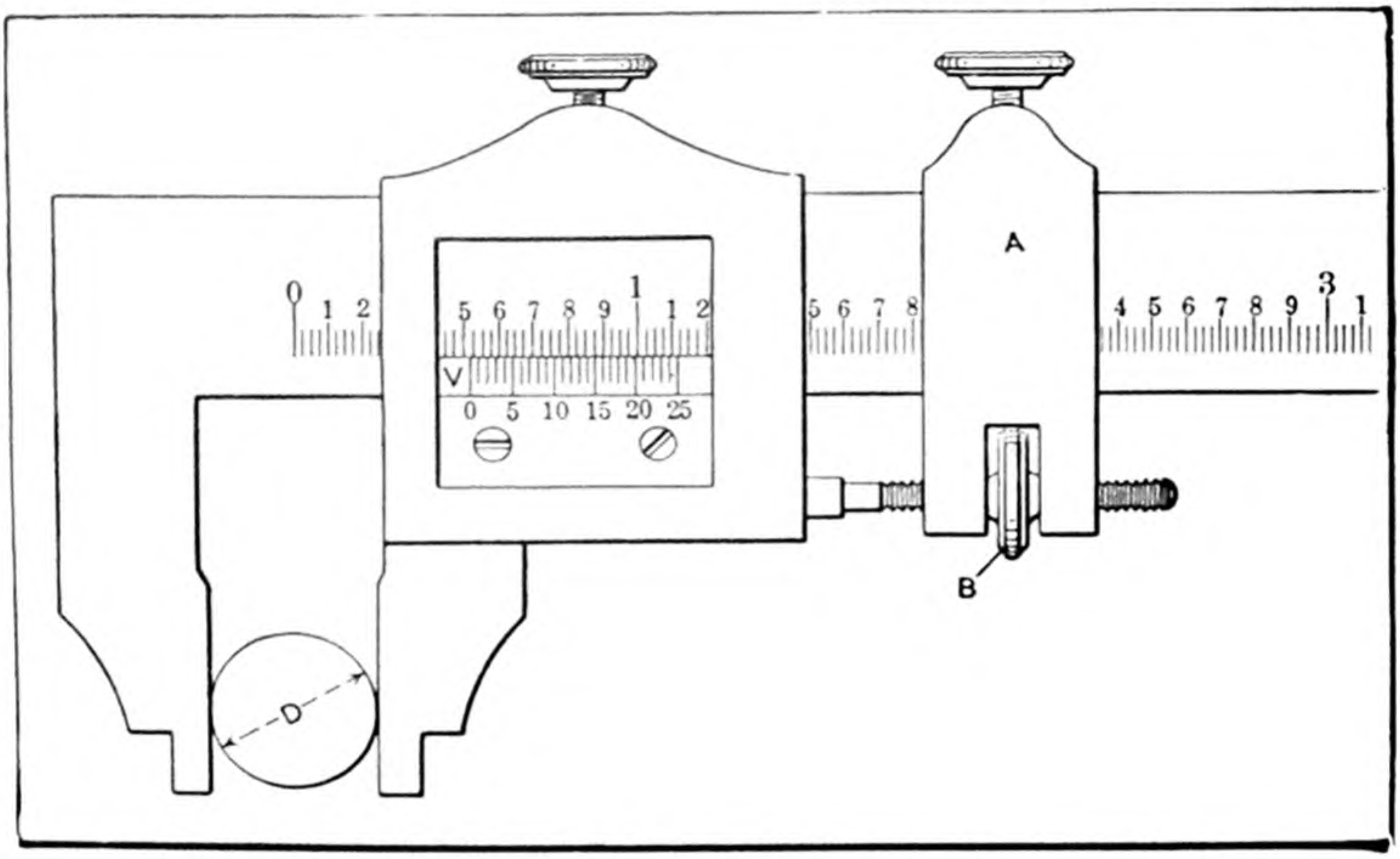
VENEER GLUE. See Glues for Wood.

VENTING. In core making, venting is the process of providing outlets for gases so that they may escape when the molten metal is poured into the mold.

VENTURI METER. The Venturi meter is an instrument for accurately measuring the discharge of fluid or gas through a pipe. The meter consists essentially of an hour-glass shaped section of pipe with smoothly rounded internal walls into which two gages are fitted, one at a point where the pipe is of full diameter, and one at the smallest section or opening in the pipe. By means of the pressure recorded by the two gages and the use of certain constants that have been calculated for various diameters of pipe, the discharge through the pipe may be determined.

VERNIER CALIPER AND SCALE. The vernier is an auxiliary scale that is attached to vernier calipers, height gages, depth gages, protractors, etc., for obtaining the fractional parts of the subdivisions of the true scale of the instrument. The true or regular scale of the vernier caliper shown in the illustration, is graduated in tenths of an inch, each tenth being divided into four parts, or in fortieths of an inch, but by means of the vernier scale V, which is attached to the sliding jaw of the instrument, measurements within one-thousandth of an inch can be taken. The vernier, in this case, makes it possible to divide each fortieth of an inch on the true scale into

twenty-five parts. To measure the diameter *D* with a vernier caliper, note the distance that the vernier scale zero has moved to the right of the zero mark on the true scale. This dimension may be read directly in thousandths of an inch, by calling each tenth on the true scale that has been passed by the vernier zero, one hundred thousandths, and each fortieth, twenty-five thousandths, and adding to this number as many thousandths as are indicated by the vernier. The vernier zero in the illustration is



Vernier Caliper

slightly beyond the five-tenths division; hence, the reading is 0.500 plus the number of thousandths indicated by that line on the vernier that exactly coincides with one on the scale, which, in this case, is line 15, making the reading $0.500 + 0.015 = 0.515$ inch.

Rule for Reading a Vernier. — The following is a general rule for taking readings with a vernier: Note the number of inches and whole divisions of an inch that the vernier zero has moved along the true scale, and then add to this number as many thousandths, or hundredths, or whatever fractional part of an inch the vernier reads to, as there are spaces between the vernier zero and that line on it which it coincides with one on the true scale.

In order to determine the fractional part of an inch that may be obtained by any vernier, multiply the denominator of the finest subdivision of an inch given on the true scale by the total number of divisions on the vernier. For example, if the true scale is divided into fortieths and the vernier into twenty-five parts, the vernier will read to thousandths ($40 \times 25 = 1000$).

If there are sixteen divisions to the inch on the true scale and a total of eight on the vernier, the latter will enable readings within one hundred twenty-eighths of an inch to be taken ($16 \times 8 = 128$). It will be seen then that each subdivision on the true scale can be divided into as many parts as there are divisions on the vernier.

VERNIER OF RETROGRADE FORM. This is a vernier in which the divisions of the vernier are larger than the divisions on the main scale. Generally the divisions on verniers are made smaller than the divisions on the main scale, and such verniers are known as *direct.*

VERTEX. The vertex of an angle is the point where the two lines forming the angle intersect.

VERTEX DISTANCE. The vertex distance of a bevel gear is the distance measured in the direction of the axis of the gear from the corner of a tooth at the large end to the vertex of the pitch cone. The vertex distance at the small end of the tooth is similarly measured.

VERTICAL BORING MILL. This type of machine tool, commonly referred to as a "boring mill," has a circular table which revolves about a vertical axis so that the work-holding surface is horizontal, thus making it comparatively easy to place in position and hold large circular castings such as flywheels, cast-iron covers, etc. See Boring Machines.

VERTICAL TURRET LATHE. Machines called vertical turret lathes are similar in their general design to a vertical boring mill which has a side head. See Turret Lathe Classification.

VIBRATION DUE TO STEAM FLOW. Steam, when flowing at a high velocity in the supply pipe of a high-speed engine, is alternately stopped and raised again to this high velocity several hundred times a minute, due to the rapid opening and closing of the steam valves. This intermittent motion of the steam has, in many cases, been found to cause vibration in the engine supply pipe, which, in turn, is transmitted to other branches of the system. Vibration is also caused by suddenly changing the direction of steam flow through tees and short-turn elbows, and sometimes by the unequal velocity of steam flowing through different branches of the piping system. Vibration, combined with expansion and contraction strains, is a constant source of danger. The pipe should be so proportioned that the velocity will be as nearly uniform as possible in all branches of the system. The engines should be equipped with steam separators of large capacity to cushion the steam, at or near the engine throttle, and the piping should be firmly anchored at suitable points.

VIBRATION OF STRUCTURES. Every part of a building — beams, floors, columns, walls, etc., in fact the entire building itself — has its natural pitch of periodic number of vibrations which will result when it is set in motion. If the cause be intermittent and of a different frequency from that of the structural features, the result will be a breaking up of vibrations except for those intervals when they get in step; then the natural action will be exaggerated. The effect of coincidence between the natural frequency of vibration of a floor and that of its source of disturbance is well illustrated by the following experience in connection with the testing of a small engine upon a floor of timber construction. At a speed of about 550 revolutions per minute, the intensity of the floor vibration was so great that it was impossible to work in the drafting-room located on the same floor more than 100 feet away; but this effect entirely disappeared when the speed was either increased or decreased about 50 revolutions per minute. When the disturbing force is represented by a number of machines running at practically the same speed, the effect may be like that of dancers upon a floor or soldiers marching over a bridge, and prove destructive to the entire structure if the step time coincides with its natural pitch.

VIBROSCOPE. The vibroscope is an apparatus which is used in examining rapidly moving mechanisms in order to study the causes of extreme vibration or other operating characteristics. By means of this apparatus a rapidly moving part appears stationary. A special electric lamp is used to illuminate the moving part by a series of instantaneous flashes so timed that the part under observation is only lighted when in whatever position it is to be observed. This succession of flashes occurs so rapidly that the part appears to be stationary, or if desired, it can apparently be given a slow motion similar to the effect of a slow-motion moving picture, merely by a gradual change between the flashes and the position of the moving member. The vibroscope consists (1) of a lamp containing a special Neon tube of unusual design, which gives illumination far in excess of that ordinarily obtained in any vacuum tube, and at the same time, the flash is of extreme rapidity; (2) means of supplying the electrical discharges to illuminate the tube; and (3) a device for regulating the flashes of light in synchronism with the movements of the mechanism under examination. The light flashes are controlled by an interruptor which is preferably driven direct from a shaft of the mechanism under observation so that the flashes will automatically be in synchronism with the movement of the mechanism. Rotary movement is imparted to the shaft of the interruptor through the medium of a steel or rubber driving point which is held in contact with the center on the shaft of the machine under examination; or if necessary, a direct coupling may be arranged. A cam

is mounted on the interruptor shaft which operates a contacting device. The interruptor is in two parts, one of which may be rotated concentrically upon the other. On turning the outer part, the timing of the flashes is changed; thus if it is turned in the direction of rotation, the part under observation will appear to move forward slowly when viewed under the rays of the light, and similarly, if it is turned in the opposite direction, the part will appear to rotate backward. Hence the mechanism may apparently be brought to rest in any desired position in the cycle of operations.

When the switch is turned on, the light will flash at the same speed as the rotation of the shaft, and any of the moving parts of the machine that are brought under the rays of the light will immediately appear stationary, irrespective of whether the motion is rotary, reciprocating, or vibratory, provided the drive for the interruptor is rotary. Above a certain speed the flashes are woven into a continuous picture. Direct rays of daylight from a window may cause some inconvenience, but screening of these rays is all that is necessary. If a vibrating part is illuminated with flashes at twice its frequency, the interruptor can be set so that the vibrating part is viewed simultaneously in its two extreme positions; in other words, a double image of the vibrating part will be shown and from the distance apart of the two images, a measurement of amplitude can be obtained. See also Stroboscope.

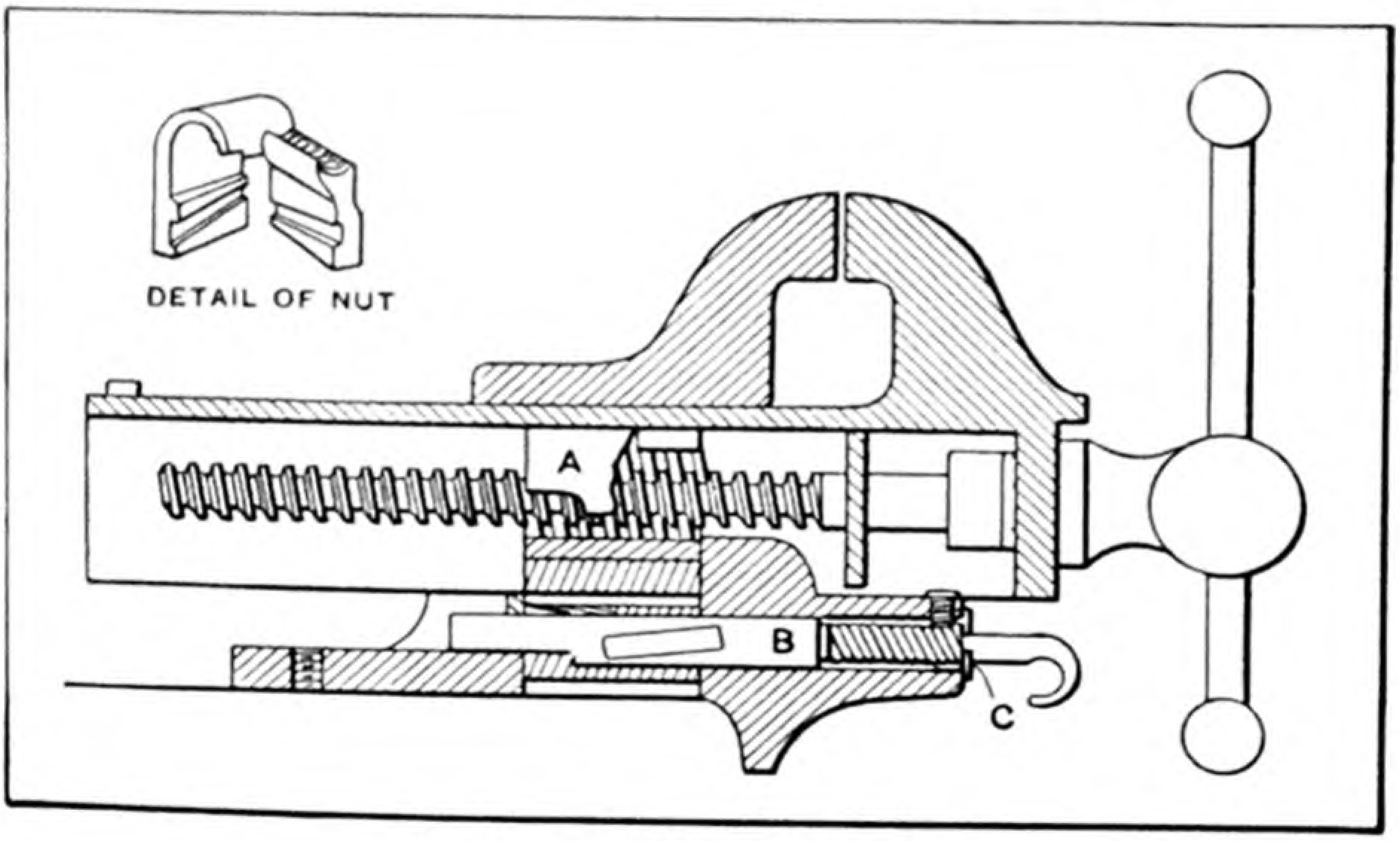
VIRGIN COPPER. Virgin copper, also known as malleable copper and native copper, is found in nature practically pure, having all the properties of refined metal. Virgin copper is mined extensively in the Lake Superior district in the United States, and also in Bolivia.

VISCOSITY OF OILS. The viscosity of an oil or other fluid is the resistance offered to a flowing movement or the fluidity, which is affected by the internal friction and resulting variations in the relative motion of the particles. As the temperature of oils rises, the viscosity decreases. Animal or vegetable oils maintain their viscosity better than those of mineral origin. Mineral oils lose their viscosity with a rise of temperature more rapidly than the fixed oils (animal or vegetable), but the difference between the two classes of oils, in this respect, diminishes considerably for temperatures above 100 degrees F. (or 150 degrees F., in the case of cylinder oils). Experiments were undertaken to determine the relation between viscosity and the wearing and lubricating qualities of oils, and the effect of the constituents of various oils on the lubricating qualities. Twenty-two oils were tested, the method of procedure being to find the chemical composition and viscosity of each oil, and then use it as a lubricant in a journal bearing The experiments showed that the viscosity of an oil affects its lubricating quality in the following way: If the oil is adapted to the load put upon it, then the lower the viscosity, the better the oil as a lubricant. The oil,

however, must conform to the character of the load, a light oil being unsuitable for heavy loads.

VISES. Clamping and holding tools called *vises* are used in machine shops for many purposes, both in connection with bench work and for holding parts on machine tools. For general hand-fitting operations, vises are usually fastened to a bench. *Machine vises* are used in milling, drilling, and other machining operations instead of special jigs or fixtures, and on some classes of work requiring high production and rapid operation, special jaws of suitable form are used. Vises of this kind are operated either by a screw or by means of a link and cam controlled by a hand lever, the latter type having largely superseded the former in interchangeable manufacture.

The illustration shows an example of a *quick-acting vise*, which is so constructed as to permit a rapid adjustment of the jaws. In this design, a



Quick-acting Machinist's Vise

nut *A*, formed of two pieces (as shown in detail in the upper part of the illustration), is either opened or closed on the operating screw by means of the operating bar *B* which has two tapered tongues as indicated. By means of these tongues, one-half of the nut is moved upward and the other downward, for releasing it from the screw. The operating bar is provided with a ratchet catch *C*, which, when engaged, holds the nut open during adjustment. The illustration shows the nut disengaged from the operating screw, and the jaw, therefore, free to be moved as desired. Another type of quick-acting vise employs a lever at the side of the vise, which, by means of a toggle action, engages a dog with a ratchet which is cut on the side of the slide, and thus moves and locks the jaws. Approximate adjustments are quickly made by hand in this type of vise by sliding the jaw in or out.

VISE, UNIVERSAL BALL. See Universal Ball Vise.

VIS-VIVA. The Latin expression *vis-viva* ("living force") was used by many early writers on mechanical subjects to denote the energy stored in a moving body. The expression is never used at the present time, the word "energy" having taken its place. The *vis-viva* was defined by some writers as the product of the mass multiplied by the square of the velocity (mv^2), and by others as one-half of this quantity ($\frac{1}{2}\ mv^2$). The latter value is the same as that now defined as *energy*.

VITRIFIED GRINDING WHEELS. Grinding wheels, in which the bond holding the small particles of abrasive is composed of suitable clays and flux, baked or burned continuously until the clay is partially melted and vitrified, are known as *vitrified* grinding wheels. Vitrified wheels are extensively used for cylindrical grinding, for surface grinding when a disk form of wheel is used, for internal grinding, cutter grinding, and for many other purposes. They can readily be distinguished from other wheels by the reddish or reddish-brown color and the clear ringing sound produced when they are tapped; they are porous and free-cutting and are not affected by water, acids, oils, heat, or cold.

VOLT. The unit of electromotive force is known as the *international volt*, which is the electromotive force which, when steadily applied to a conductor the resistance of which is one ohm, will produce a current of one ampere. The volt is determined, for practical purposes, by comparing it with the electromotive force between the poles or electrodes of the voltaic cell known as *Clark's cell*, at a temperature of 15 degrees C. (59 degrees F.), which cell develops an electromotive force of 1.4328 volt.

VOLTAGES. The voltage generally used for lighting and industrial power purposes is 125 and 250 volts, and for street railway systems, 500 volts. The demand for still higher voltages for interurban and trunk railways has led to the design of generators for 1200 and 1500 volts, which are operated singly or two in series so as to give an operating voltage of 2400 and 3000 volts.

VOLTAMETER. The voltameter is a device in which the passage of a current through a solution produces a chemical effect which can be measured. In one of its oldest forms, the current decomposes water into its gaseous elements, oxygen and hydrogen, the volume of which, collected in a test tube, forms a measure of the average current strength. In the *silver voltameter* used in laboratories as a primary standard for determining current strength, the weight of silver deposited from a solution in a given time is a measure of the average current value during that time.

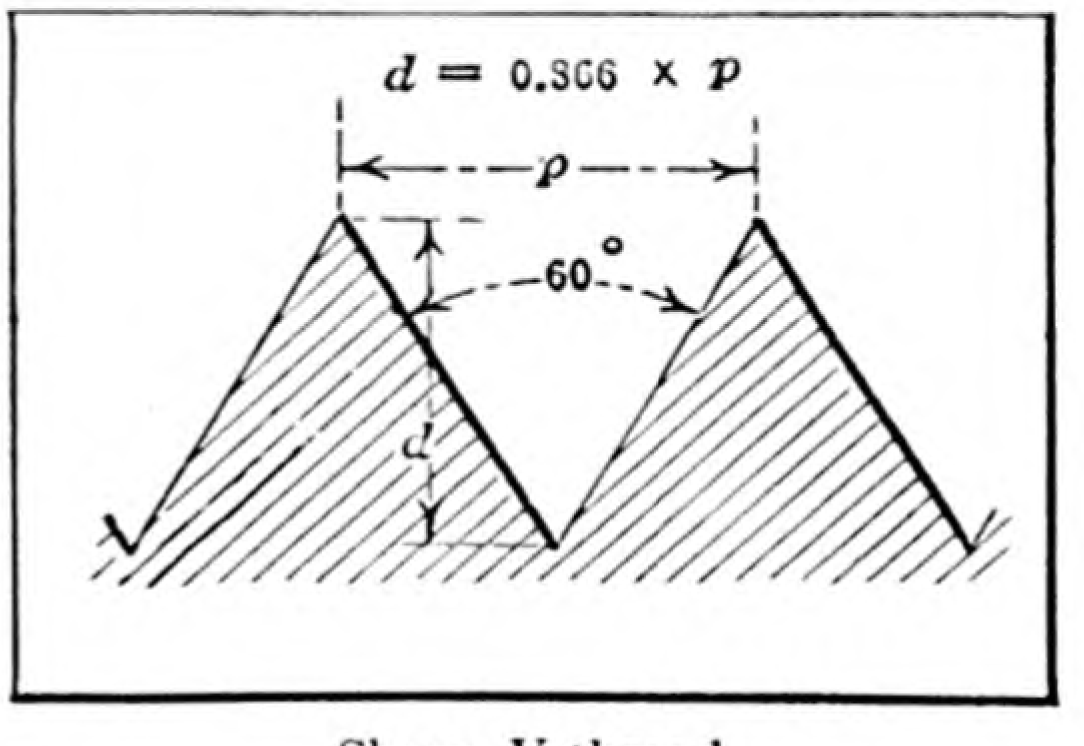
VOLTA'S PILE. This term refers to a means for transforming chemical energy into electrical energy employed by Volta in 1799, consisting of alternate disks of zinc and copper with a wet cloth or blotting paper between the disks.

VOLTMETER. A voltmeter is an electrical measuring instrument which indicates the voltage of an electric current; that is, it measures the potential difference between the two points to which its two terminals are connected. Any type of ammeter or amperemeter may be used as a voltmeter, if the coil is especially designed for this purpose.

VOLTMETER SWITCH. A rotary type voltmeter switch is one which is used for connecting one voltmeter to various circuits. The switch consists of a number of stationary contacts arranged in a circle, to which the circuits are connected. Just inside of the stationary contacts are located stationary contact segments to which the voltmeter is connected. An arm pivoted at the center of the circle carries contacts which are arranged to make contact between the stationary contacts and the stationary segments, and, as the switch is rotated from point to point, it connects the meter up with the various circuits.

VOLUMETRIC EFFICIENCY. In air compression, volumetric efficiency is the ratio of the actual volume of air taken into the cylinder per stroke to the piston displacement. It varies with the amount of clearance and with the terminal pressure. It is usually 90 per cent or over in the best classes of machines, but may fall considerably below this figure in the case of small machines of poor design and construction.

V-THREAD. The top and bottom or root of this thread form are theoretically sharp (see illustration), but in actual practice the thread is made with a slight flat, owing to the difficulty of producing a perfectly sharp edge and because of the tendency of such an edge to wear away or become battered. This flat is usually equal to about one twenty-fifth of the pitch, although there is no generally recognized standard. Owing to the difficulties connected with the V-thread, the tap manufacturers agreed in 1909 to discontinue the making of sharp V-thread taps, except when ordered. One advantage of the V-thread is that the same cutting tool may be used for all pitches, whereas, with the U. S. standard form, the width of the point or the flat varies according to



Sharp V-thread

the pitch. This is one of the reasons why many V-threads are still in use. The V-thread is also regarded as a good form where a steam-tight joint is necessary, and many of the taps used on locomotive work have this form of thread. The sides of the thread form an angle of 60 degrees with each other. If p = pitch of thread, and d = depth of thread, then:

$$d = p \times \cos 30 \text{ deg.} = 0.866\, p = \frac{0.866}{\text{No. of threads per inch}}.$$

The U. S. standard screw thread is used largely in preference to the sharp V-thread because it has several advantages: As the U. S. standard thread has a flat top, it is not so easily injured as a sharp V-thread, and taps and dies wear less at the points of the teeth and retain their size longer for the same reason. Moreover, U. S. standard screw threads are from one-eighth to one-sixth stronger to resist tension than screws with V-threads, because for a given outside diameter there is a larger root diameter or effective area.

VULCANITE GRINDING WHEELS. The abrasive grains of vulcanite wheels are bonded by the use of vulcanized rubber. Very hard, tough, thin wheels can be produced. Vulcanite wheels, like those of the elastic type, are made very thin, and are adapted for cutting off tubing, wire, thin sheets of steel or brass, and parts that are difficult to hold for cutting by regular tools. For general cutting-off operations, when the speed of cutting is not an important factor, vulcanite wheels are generally considered preferable to elastic wheels. The latter, however, can be used to better advantage for cutting off tempered tool steel or alloy steel tools, when cool cutting is important, because of their softer grades and cooler grinding action.

WAGE SYSTEMS. The two fundamental methods of paying for labor are (1) to pay the workman according to the amount of time expended or (2) to pay him according to the amount of work that is done. All wage systems are either based directly upon the time or amount of production, or they are combinations of these two methods of payment. A wage system cannot properly be classified as good unless it is fair both to employer and employe, and this principle has been generally recognized in the development of modern wage systems.

WAGE SYSTEM, BONUS. The straight bonus system is so arranged that the workman receives, in addition to a daily wage, a fixed amount or bonus whenever a piece of work is finished within or less than the predetermined time. Assume that the bonus is equal to one-third the amount that would be earned in the time set for a given job; then, if the work is supposed to require nine hours and it is done in eight hours, a bonus equal to three hours' pay would be given in addition to the regular rate of pay for the actual working time. For instance, if in this case the hourly rate were sixty cents, the total amount received for the job would equal 4.80 + 1.80 = \$6.60. If the work had been done in seven hours, the total amount received would equal 4.20 + 1.80 = \$6.00. The time saved by doing the work more quickly is, of course, expended on the next successive job. In case the time set for the job is exceeded, the wage is then based on the regular hourly rate.

Gantt Task and Bonus System. — The task and bonus system, introduced by H. L. Gantt, differs from the "straight bonus system" previously referred to, in that the workman is paid the full time allowed for the task and, in addition, a bonus equivalent to one-third of the full task time, when work is finished within the task time. For instance, if the task time is three hours; the regular fixed rate, sixty cents per hour, and the work is done in two hours, the workman would receive pay for the full time, or \$1.80 plus a bonus of sixty cents. Thus, in effect, the hourly rate was increased by doing the work in less than the task time, in addition to the bonus received. With the straight bonus system, he would receive sixty cents an hour for the two hours of actual working time (instead of pay for the entire task time), and, in addition, a bonus. If the bonus were one-third of the task time as before, the total amount received would equal 1.20 + 0.60, as compared with \$2.40 under the Gantt system. If the work is not done within the task time under the latter system, the regular hourly or daily rate is received.

WAGE SYSTEM, DIFFERENTIAL. The differential wage system introduced by F. W. Taylor depends upon accurate knowledge as to the length of time required to do the work as determined by the methods con-

nected with scientific management, and it is intended to reward liberally the efficient workmen and to penalize the inefficient who produce less than the required standard, by giving them a relatively low rate of pay. The important feature of the original plan is that there are two piece rates, one being high and the other low. The higher rate applies when the work is completed within the prescribed time as determined by careful observation and study, and the lower rate, when this standard time is exceeded. In order to illustrate this system by a practical example, suppose a careful investigation has shown that ten pieces per day represents a maximum number. Then, under the differential system, if a workman finishes ten pieces per day and all of these pieces pass inspection, he receives, say, 70 cents per piece. On the other hand, if the work is done too slowly and only eight pieces are finished, then, instead of receiving 70 cents per piece, the rate might be reduced to say 60 cents per piece. If ten pieces are finished but some of them are imperfect and will not pass inspection, the low rate of 60 cents may be still further reduced, the amount of reduction depending upon the circumstances. As the preceding example shows, whenever a workman is producing the maximum amount, either for a day or a shorter period, he receives the higher wage rate, but when there is a reduction, either in quantity or quality, the pay is also reduced and becomes less than the ordinary rate of pay.

WAGE SYSTEM, EMERSON. The plan of the Emerson system of payment is to reward workmen who are reasonably efficient and to increase the reward or bonus as the efficiency of the workman increases. Each workman is assured of a fixed daily wage and has an opportunity of earning, in addition, a bonus depending upon the relation of the actual production to a certain fixed standard. The standard performance is first established by making a careful study of all the controlling factors. The workman receives a bonus equivalent to 20 per cent of the daily wage for work done in the standard time, as his efficiency would then be 100 per cent. If the standard time were eighteen hours and the job were completed in twenty hours, the workman's efficiency, as compared with the standard time, would be 90 per cent and he would receive a bonus of 10 per cent; if his efficiency were 80 per cent, the bonus would be reduced to $3\frac{1}{4}$ per cent, and, if the efficiency were less than 67 per cent, there would be no bonus at all. In case the work were done in less than the standard time, so that the efficiency were over 100 per cent, the bonus would increase until it was equivalent to 60 per cent of the wages for an efficiency of 140 per cent. In the practical application of this system, the bonus is calculated with reference to the work for some period such as a week or a month, and not for individual jobs. For instance, if the standard time on all the different jobs handled by one man in a month

amounted to 200 hours, and the actual working time had been 220 hours, the efficiency of that particular workman would equal $\frac{200}{220} = 90$ per cent, approximately; therefore, the bonus in this case would be about 10 per cent. If the hourly rate were 70 cents, the amount based upon the regular daily wage would equal $220 \times 0.70 = \$154$ and as the bonus is 10 per cent of the wages, the total amount would equal $154 + 15.40 = \$169.40$.

This progressive method of rewarding efficiency is intended to hold the interest of the workmen even when conditions for any one job are not favorable, and it is apparent that the work cannot be done within the standard time. The standards are established after careful and reliable investigations have been made, including time and motion studies. It may be necessary, of course, to change the time standards to suit new conditions or equipment, and the rate of pay may also be varied, but the time standards should not be changed to affect wages as they are based strictly upon analytical observations of the different factors affecting production.

A modification of the Emerson system advocated by C. E. Knoeppel differs from the former in the amount of bonus paid at the beginning and also when an efficiency of 100 per cent has been obtained. The workmen who are over 67 per cent efficient receive a larger bonus than with the Emerson system, especially during the earlier stages from 67 to 85 per cent, and when an efficiency of 100 per cent is exceeded, there is an additional bonus of 5 per cent added to the 20 per cent received under the Emerson system. This 5-per-cent premium is an extra incentive for increasing production beyond the 100 per cent mark. With either of these systems, the cost per piece decreases slightly instead of remaining constant as with the straight piece-work plan.

WAGE SYSTEM FOR FOREMEN. There are several plans by which foremen and inspectors are paid in proportion to output. One plan pays them in proportion to the average piece work earnings of workmen in the department. Another plan, where group bonus is used, either considers the foreman and inspector as members of the group, or pays them the same percentage of increase which the group earns. A third plan pays the foreman in proportion to the savings which he succeeds in making in total departmental expense, as measured by actual expense compared with standard budget.

WAGE SYSTEM, PARKHURST. The Parkhurst differential bonus system differs from the Emerson wage system in that it is separate from and independent of the time rate. The day wage is guaranteed, and is at least as high as the prevailing wage in the district. The day rate and the bonus

are paid in separate envelopes, so that they may be kept distinct in the workman's mind. The time wage is paid after the usual manner of individual agreement of collective bargaining, having no relation directly to the individual task. The bonus, on the other hand, is a thing apart, and is based on individual effort. This system is, however, comparatively complex and not readily understood by many workmen.

WAGE SYSTEM, PIECE-WORK. The piece-work system is based upon the plan of paying a workman who is producing or operating on duplicate parts a certain amount for each piece of work that is completed. One of the fundamental difficulties with the piece-work system, as ordinarily installed, is in determining how much should be paid for a given operation, or the price per piece. Frequently the rate is entirely too high at first, in which case the usual result has been that the workman made an exceptionally high wage until the rate was reduced. On the contrary, a rate that is too low makes it impossible for the employe to obtain a fair daily wage until an adjustment is made and this change may be delayed unnecessarily. If the rate enables the workman to earn much more than he could under the day-wage system, he may be allowed to do this temporarily or until the management has definitely determined just how much it is possible for the workman to produce; the rate per piece is then reduced and, in many cases, the final result is that the workman receives about as much as he did formerly, but produces a great deal more; consequently, this system of payment is not regarded favorably by most workmen and its theoretical advantages as a means of decreasing production cost are modified in practice because many employes, instead of attempting to earn as much as possible, aim to produce just enough to earn a moderate wage in order to avoid a reduction of the piece rate. The cost of inspection is relatively high with the piecework system, as a general rule, because there is a tendency to slight the work, although trouble from this source may not be very serious when each man is held strictly accountable for rejected parts.

WAGE SYSTEM, PREMIUM. The Towne-Halsey premium system was developed to overcome the inherent defects of the piece-rate system. It is based on the principle that a fixed daily wage should be guaranteed and that extra payment should be given whenever a job is finished in less than the alotted or standard time, the amount of extra pay depending upon the amount of time saved. The plan is to record the quickest time in which the work has been done and use it as a standard. If the workman succeeds in finishing the operation in less than the standard time he receives, in addition to a regularly hourly rate, a premium, which may vary from one-quarter to one-half the difference between the wages actually earned and what would have been earned if the full time had been utilized. In order to illustrate

the practical working of this system, suppose an employe receives seventy cents an hour, so that his minimum guaranteed wage for an eight-hour day is \$5.60, and that a premium equal to 40 per cent of the difference between the actual working time and the standard time is given. If the standard time for a given job is six hours and the work is finished in five hours, the employe receives the regular hourly rate of seventy cents for five hours, or \$3.50 and, in addition, 40 per cent of the difference between the pay for six hours' work and the pay for the actual working time. The difference in this case is seventy cents ($4.20 - 3.50 = \$0.70$) and 40 per cent of seventy equals 28 cents, which represents the premium. Therefore, the total wage for five hours equals $3.50 + 0.28 = \$3.78$, and during the three remaining hours of the day the employe will earn, in addition, at least \$2.10, and more than this, if he continues to do the work in less than the standard time.

One fundamental defect of this or any other wage system requiring a standard time for a task, when applied in conjunction with an ordinary system of management, is in determining with accuracy just what the standard time should be. In one case, the time may be based on favorable conditions or upon the performance of a fast workman, whereas another standard time for a task may be determined under less favorable conditions, unless time studies are resorted to and the standard time is based on a careful analysis of the conditions. The premium plan, however, is simple and easily introduced and it has proved successful in many shops and factories.

Rowan Modification of Premium Plan.—With the premium system previously described, it is to the advantage of the workman to have the standard time as large as possible, because the greater the difference between the standard time and the actual working time, the larger the premium; therefore, the tendency of the workmen, when new work is being started, is to make the standard time larger than is necessary. One method of meeting this difficulty is to make the premium a percentage of the amount received for the actual working time at the regular day rate. This percentage, according to the Rowan plan, is equivalent to the percentage of standard time that is saved.

If A equals the amount received for the actual working time at the regular day rate; B equals the standard time in which the work should be completed; and C equals the amount of time saved, the premium may be computed as follows: Premium $= A \times \frac{C}{B}$. For example, if the standard time is eight hours and the actual working time, six hours at sixty cents an hour, the premium equals $360 \times \frac{2}{8} = 90$ cents, and the total amount received in this case equals $360 + 90 = \$4.50$.

With this system, the premium is decreased as the amount of time saved increases, and if it were possible to save 90 per cent of the standard time, the premium would be the same as when the saving was only equal to 10 per cent of the standard time. The workman, however, receives a more liberal premium for a moderate change in time than he does with the Towne-Halsey premium system. The Rowan plan has been objected to on the ground that it discourages honest efforts on the part of workmen to obtain maximum production, but, on the other hand, there is less tendency on the part of the employer to reduce the basic rate. This system has been applied quite extensively in England.

WAGE SYSTEM, "STANDARD HOUR." The "standard hour" method of wage payment is a modification of the piece rate system to avoid the difficulty which arises when a general change in wage level must be made. Under this plan the standard time is set as if for a piece rate. The standard amount of work per hour is established, and for each multiple of this quantity which a workman produces he receives his hourly rate. Usually a chart is furnished showing the standard amount per hour, and sometimes a supplemental table showing the equivalent rate per piece at current hourly rates. This method is a piece rate with the rate left off. It is as simple as the piece rate, but readily permits changes in wage level, and also allows varying rates for different operators. When a standard hour's work is carefully set, it can be guaranteed permanently, because it is independent of wage changes.

WALLOON PROCESS. See Wrought Iron Manufacturing Methods.

WALSCHAERTS VALVE MOTION. The Walschaerts valve-gear which has been used extensively on locomotives, is so arranged that the valve receives its motion from two sources: the cross-head and an eccentric crank. The Walschaerts gear is more accessible than the Stephenson motion in that it is applied outside the wheels and requires only a single eccentric return crank and a connection to the cross-head for its operation. The eccentric crank may be a comparatively small pin attached to the main crank, and it does the work of the two heavy eccentrics of the ordinary gear. This arrangement leaves the entire space between the frames clear for bracing the frames. The Walschaerts gear as compared with the Stephenson, causes a more uniform steam distribution with a lower percentage of preadmission, to which is added a constant and moderate amount of lead for early cut-off, although on the resultant economy in steam consumption there can be but slight difference when both the gears are in a first-class condition.

WARDING FILE. A warding file has parallel faces, that is, it is of the same thickness throughout, but it is tapered in width for the whole length

from the heel to the point. It is generally double-cut, and is used by jewelers and machinists, but especially by locksmiths for filing "ward notches" in keys; hence, the name "warding file."

WASHBURN & MOEN WIRE GAGE. This gage is the same as the American Steel & Wire Co's. gage, which, as approved by the Bureau of Standards at Washington, is now known as the "Steel Wire Gage." This gage applies to all steel wire, and is used to a greater extent than any other steel wire gage in the United States. See Gages for Wire.

WASHED METAL. Washed metal is a name used for cast iron from which most of the silicon and phosphorus have been removed, by the so-called "Bell-Krupp process," without removing much of the carbon contents, so that the metal still contains enough carbon (over 2.2 per cent) to be classified as cast iron.

WASHERS. Plain washers for use under nuts are generally made to certain standard dimensions such as the "Manufacturer's Standard," and the S. A. E. standard, but many manufacturers make washers to dimensions adopted by them especially for their own work, and do not follow any generally accepted standard. The S. A .E. standard lock washers are, before compression, similar to one turn of a helical spring formed of square steel stock. When the washer is compressed it exerts a pressure on the nut which tends to prevent the nut from turning. The washers for S. A. E. and U. S. standard bolts are of two classes; namely, the heavy section for general use and the light section for optional use against soft metal.

WASH-OUT HOLE. In a steam boiler, a wash-out hole is an opening large enough for the hand and arm to enter the boiler for washing out, and for inspection purposes.

WASH-OUT TAPS. Mud and wash-out taps are used in boiler work, the same as taper boiler taps and patch-bolt taps. These taps are sometimes referred to as *arch pipe taps*, but the former name is the more common. They taper $1\frac{1}{4}$ inch per foot, and have 12 sharp V-threads per inch.

WASTE, COTTON AND WOOLEN. There are two principal classes of waste. One class is intended for cleaning purposes and the other for holding a lubricant, as, for example, when used as a packing material in the journal boxes of railway cars or in some classes of motor bearings. The various grades of cotton waste comprise the first class, whereas wool waste comprises the second class, which is used as packing. The cotton or cleaning waste is by far the most important commercially, if judged by the extent of its use. The most essential property of waste is its oil-absorbing quality. Poor

waste is soon saturated with oil or grease, whereas good waste will absorb much more oil and may be turned inside out and used again. A high absorbing quality is desirable both in cotton and wool waste, but the importance of this feature might easily be overlooked, especially in the case of waste used exclusively for cleaning purposes. To obtain a waste capable of absorbing the greatest amount of oil and grease, it is essential, in the first place, to use the right kinds of raw materials and, second, to mix these materials thoroughly and separate the various threads or fibers completely, so that there are no solid masses or large thick strands extending through the waste.

WASTE RECLAMATION. Oily and otherwise soiled waste and wiping cloth can be reclaimed at about 20 per cent of the cost of new material. The process of reclamation can be repeated from ten to thirty times, according to the quality of the material. The apparatus consists mainly of a washing machine used in connection with drying machines.

WASTING. The term wasting refers to a general corrosion in boilers acting in a uniform manner over a large surface. Sometimes the action is confined to a narrow belt at the water level. Braces and stays are liable to the effects of wasting and, therefore, require regular inspection.

WATER BRAKES. All the power absorbed by a Prony brake is transformed into heat. When the amount of power to be absorbed is considerable, the Prony brake becomes unsatisfactory for the reason that it is impossible to conduct away such enormous quantities of heat, and avoid temperatures which will be destructive both to the pulley and to the brake. In such cases, some form of water brake is generally used. A water brake usually consists of a casing in which disks or paddles revolve and churn or agitate a quantity of water contained in the casing. The disks or paddles are fixed to a shaft which delivers the power to be absorbed. The casing is free to turn about the shaft, and an arm extending from it rests upon some form of weighing apparatus. Vanes or ribs fixed to the casing prevent the water from turning with the rotating member. The same formulas are employed in computing the power absorbed as are used in the case of a Prony brake. In order to carry off the heat generated, the water which is agitated is allowed to flow away and is continuously replenished by fresh cold water. The power absorbed by a brake of this type depends upon the speed and upon the quantity of water which is agitated. Other things being equal, the power absorbed is approximately proportional to the cube of the number of revolutions per minute.

WATER-CARBIDE GENERATOR. This is an acetylene generator in which water is brought into contact with carbide, the carbide being in excess.

There are three types of this kind of generator, those in which water rises into contact with the carbide, those in which it drops upon the carbide, and those in which a container filled with carbide is slowly lowered into the water and again raised when the gas generation becomes excessive. The best form is generally considered to be that in which the water rises slowly until it comes into contact with the carbide.

WATER FLOW MEASUREMENT. See Weir; also Flow Meter.

WATER FOR BOILERS. See Feed-water Heating; Feed-water Impurities.

WATER GAS. See Gas Production.

WATER GLASS. This is a glass tube used on steam boilers to indicate the height of the water level in the boiler. It consists mainly of a vertical tube mounted into pipes connecting with the boiler. The lowest visible part of the glass tube should be not less than 2 inches above the lowest permissible water level.

The term "water glass" is also applied to a substance consisting of silicates of sodium or potassium, or of both. The commercial form of water glass may be a stony powder, a glassy mass, or, when dissolved in water, a viscous syrupy liquid.

WATER-PACKING. The pistons of dashpots and similar apparatus that must move with a minimum of frictional resistance are commonly grooved to reduce the slip or leakage of liquid past the piston, but packing rings are not used. The grooves are generally called "water-packing" grooves, because water, oil, or other liquid under pressure accumulates in the grooves, and by capillary attraction and the setting up of eddy currents, materially reduces the leakage of the fluid without causing much frictional resistance.

WATER PRESSURE. The greatest density of water occurs at 39.1 degrees F., when it weighs 62.425 pounds per cubic foot. The pressure in pounds per square inch of water that is not moving, against the sides of any pipe, vessel, container, or dam is due solely to the "head" or vertical height of the surface of the water above the point at which the pressure is considered. The pressure is equal to 0.433 pound per square inch for every foot of the head, at a temperature of 62 degrees F. For higher temperatures, the pressure decreases slightly. The pressure per square inch is equal in all directions, downward, upward, and sideways. Water is composed of hydrogen and oxygen, in the ratio of two volumes of the former to one of the latter. It boils under atmospheric pressure at 212 degrees F. and freezes at 32 degrees F. Water can be compressed only in a very slight degree, the

compressibility being so slight that, even at the depth of a mile, a cubic foot of water weighs only about one-half pound more than at the surface. The quantity of water that will be discharged through a pipe in a given time depends primarily upon the head and also upon the diameter of the pipe, the character of the interior surface, and the number and shape of the bends.

WATERPROOF COMPOSITIONS. The asphalt fluid coatings for reservoir walls, concrete foundations, brick, wood, etc., are often of use to engineers. Asphalt only partly dissolves in petroleum naphtha, but when heated in a steam-jacketed kettle and not thinned out too much, a mixture of the two may be obtained in which the part of the asphalt not dissolved is held in suspension. Asphalt is entirely soluble in benzol or toluol, which are about the cheapest solvents for all the constituents of asphalt. Tar and pitch are sometimes used in this connection, but tar contains water, light oils, and free carbon, and does not wear as well as good refined asphalt; pitch also contains free carbon, which is sometimes objectionable when it is thinned out with a solvent. Asphalt alone is somewhat pervious to water, but it can be improved in this respect by adding about one-fourth its weight of paraffin; it is also well to add a little boiled linseed oil. For thicker compositions, where body is required, asbestos, stone powder, cement, etc., may be added as fillers. Lutes of linseed oil thickened with clay, asbestos, red or white lead, etc., are waterproof if made thick enough. These are much used for steam joints. Flaxseed meal made into a paste with water is often serviceable, the oil contained serving as a binder as the water evaporates.

WATER RATE OF ENGINE. The water rate of a reciprocating engine is commonly expressed in pounds per indicated horsepower (I.H.P.) per hour. In making a test for the water rate or steam consumption, the indicated horsepower of the engine is computed from an indicator diagram, and this, divided by the total weight of dry steam supplied to the engine per hour, will give the water rate. Sometimes the water rate per delivered or brake horsepower (B.H.P.) is given. In this case, the horsepower delivered by the engine is measured directly by an absorption dynamometer, and this is used in place of the indicated horsepower in the computation.

WATER SLUGS. Probably the greatest source of danger to engines of the reciprocating type is the liability of water collecting in the steam piping system, which, unless properly drained off or stopped by a steam separator, eventually finds its way to the engine cylinders in " doses " or " slugs." This is particularly dangerous in high-speed engines, owing to the small clearance space at each end of the cylinder. Water has a great capacity for absorbing heat, and, when allowed to accumulate in the steam mains, it has a tendency to condense part of the steam flowing through them.

WATER SOFTENING PLANTS. A water softening plant includes the necessary equipment for automatically removing the impurities from feed water before it enters the boilers. Water softening is carried on under two different conditions, known as the *cold* and *hot* processes, the former being again divided into the continuous and intermittent methods, which differ only in the way of handling the water and chemicals. The cold process is generally used where there is no convenient means at hand for heating the water, and where large quantities are to be treated. The chemicals most frequently employed are lime and soda solutions. These are added to the water automatically in the right proportions as determined by chemical analysis. The precipitates thus formed are allowed to settle in large tanks, or are removed by filtration, depending upon the form of apparatus used. In the hot process, soda ash is used the same as in the cold process, but the carbonates are precipitated by heating the water by means of exhaust steam.

WATER TURBINE. See Turbine, Water.

WATER-WHEEL. A water-wheel or water turbine may be defined as a prime mover in which the potential energy of a body of water is transformed into mechanical work. The water-wheel, also commonly called a *hydraulic motor*, is in its various forms one of the simplest devices for the development of power.

Hydraulic motors may be divided into three general classes: 1. Current and gravity wheels, which utilize either the impact of the current or the weight of the water. 2. Impulse wheels and turbines, which utilize the kinetic energy of a jet at high velocity. These are commonly employed in connection with a limited volume of water under a high head, which, in practice, may vary from 300 to 3000 feet. 3. Reaction turbines, which utilize both the kinetic energy and the pressure of the water. These are employed for conditions the reverse of those under (2), that is, with a large volume of water under a low or medium head. In practice, reaction turbines are used under heads ranging from 5 to 500 feet.

The available power in any given case depends upon the fall or *head*, and the *volume* of water. In case the water is utilized for the development of power by passing through a water motor, the efficiency of the latter must be taken into consideration. For approximate work, it is customary to assume an efficiency of 80 per cent, in which case the delivered or brake horsepower may be determined as follows: Multiply the cubic feet of water passing through the motor per minute, by the head, in feet; then divide the product by 661.

WATER-WHEEL GOVERNORS. Two general types of governors are for the regulation of water-wheels and turbines. In the first of these, the transmission of energy from the governor to the speed gate or nozzle, as the

case may be, is brought about mechanically, by means of levers or gearing. The governor may be of the fly-ball type, so arranged that a movement of the spindle acts on a reversing clutch, which, in turn, engages with a train of gearing attached to the regulating shaft, thus opening or closing the gate, as may be required. Motive power for rotating the balls and operating the gearing is obtained from the main shaft by means of a belt and pulleys. The other form of governor is known as the "oil-pressure" type, in which oil, under air pressure, acting on a piston, furnishes the motive power for operating the gate or nozzle mechanism.

WATT. The watt is the unit of electrical power and, as recommended by the International Electrical Congress, in Chicago, 1893, and approved by Act of Congress, July 12, 1894, is equivalent to the work done at the rate of one joule per second. One watt also equals 0.00134 horsepower, or 0.74 foot-pound per second. It is also equal to the energy required to move one ampere per second through a resistance of one ohm. In other words, an electromotive force of one volt delivering one ampere of current per second represents a power of one watt. One kilowatt is equal to one thousand watts.

WATT-HOUR METERS. The motor-type of watt-hour meter is now in practically universal use wherever it is desired to ascertain the consumption or output of electrical energy. The dynamometer and the induction principles have been utilized in the motor elements, with eddy-current damping as the controlling force. Motor-type watt-hour meters may be classified as of the *commutator*, *mercury-motor*, and *induction* types. The latter can be used only on alternating-current circuits. The commutator and the mercury types, although capable of operation on alternating current, are now regarded as essentially direct-current meters, in view of the advantages of the induction principle for alternating-current work. The several types of watt-hour meters are built in various designs, according to their intended use, such as house, switchboard, and portable forms.

WATTMETER. A wattmeter is an electrical instrument used for measuring electric power, and is employed especially for measuring alternating-current power. Wattmeters are used both as switchboard instruments and as portable instruments. The latter are made in sizes up to 200 amperes and 750 volts. Portable instruments with larger currents and higher voltages have been made, but are not generally used.

WAVE-FORM. The shape of the curve obtained when the instantaneous values of an alternating current are plotted against time in rectangular coördinates is the wave-form. The distance along the time axis corresponding to one complete cycle of values is taken as 2π radians, or 360 degrees.

Two alternating quantities are said to have the same wave-form when their ordinates of corresponding phase bear a constant ratio to each other. The wave-shape, as thus understood, is therefore independent of the frequency of the current and of the scale to which the curve is plotted.

WAX IMPRESSIONS. A wax impression of a sample or model is sometimes required in the manufacture of articles made from metal. To make a wax impression, proceed as follows: Oil the surface, of which the impression is to be made, very slightly with a few drops of oil applied to a little waste. Then take common beeswax and melt it slowly, without boiling. Mix it with one or two tablespoonfuls of lampblack to half a tumbler of beeswax, and stir the mixture. In order to make the wax impression show up clearly, take a fine hair brush and brush a small amount of powdered graphite or rouge over the object of which the impression is to be made.

WEARING VALUE. This is a term used in the appraisal of manufacturing plants to designate the replacement value of equipment less the scrap value.

WEDGE COUPLING. A wedge coupling, also known as a vise coupling, is similar to a compression coupling which grips the two shafts to be connected with the wedging action. There are numerous designs, all of which employ some kind of a conical split inner sleeve.

WEIGHING SCALE, SENSIBILITY. See Scale Sensibility.

WEIGHT AND MASS. See Mass and Weight.

WEIGHT, EFFECT OF ALTITUDE. See Gravity.

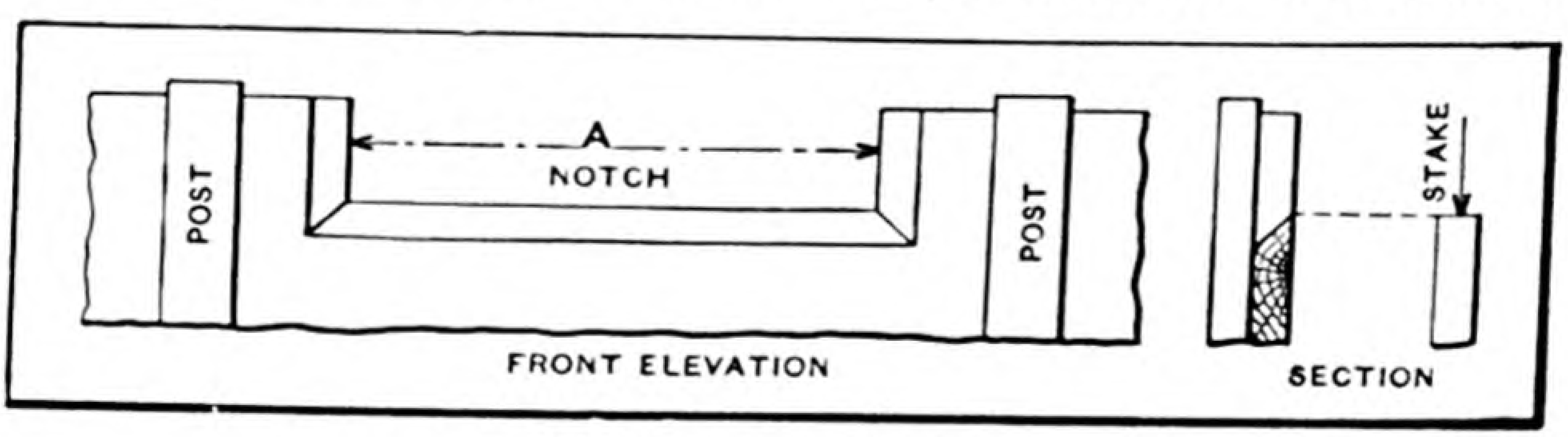
WEIGHTS AND MEASURES BUREAU. The present fundamental standards of length and mass for practically the whole civilized world result from the establishment of the International Bureau of Weights and Measures. In response to an invitation of the French government, fifteen countries, including the United States, sent representatives to a conference held in Paris in 1870, to consider the advisability of constructing new metric standards. This conference was of short duration, on account of the war then raging between France and Germany. A second conference was held two years later, at which thirty countries were represented, the United States again being among this number. At this conference, it was decided that new meters and new kilograms should be constructed to conform with the original standards of the archives, and a permanent committee was appointed to carry out this decision. The preparation of the new standards had advanced so far by 1875 that the permanent committee, appointed by the conference of 1872, requested the French government to call a diplomatic conference at Paris to consider whether the means and appliances for the final verification

of the new meters and kilograms should be provided, with a view to permanence, or whether the work should be regarded as a temporary operation. In compliance with this request, a conference was held in March, 1875, at which nineteen countries were represented, the United States being one of this number. In 1875, seventeen of the nineteen countries represented signed a convention which provided for the establishment and maintenance of a permanent International Bureau of Weights and Measures to be situated near Paris and to be under the control of an international committee elected by the conference, the committee to consist of fourteen members, all belonging to different countries.

In addition to the primary work of verifying the new metric standards, the bureau was charged with certain duties, the following being the most important: The custody and preservation, when completed, of the international prototypes and auxiliary instruments; the future periodic comparison of the several national standards with the international prototypes; the comparison of metric standards with standards of other countries. In accordance with the terms of the convention, the French government set aside a plot of ground just outside of Paris, and upon this ground, which was declared neutral territory, the International Bureau of Weights and Measures was established.

WEIGHTS, ATOMIC. See Atomic Weights.

WEIR. A weir is used in conjunction with a table of constants to determine the flow of a stream in cubic feet per minute. For definite calcu-



Construction of Weir

lations of power, the flow of the stream must be measured under standard conditions. In the case of streams up to 40 or 50 feet in width, having a maximum depth of from 3 to 4 feet, the *weir* method is the simplest and the most accurate. The general construction of a weir dam is shown by the diagram. It should be so proportioned that all of the water will flow through a space the length *A* of which shall not exceed two-thirds of the width of the stream. The bottom and ends of the open section, or *notch*, as it is called, should be beveled on the down-stream side, in order to give a sharp edge for the water to flow over. A short distance up-stream, a stake should be driven into the earth with its top on a level with the bottom of the notch. This

may be done either by the use of a spirit level or by adjusting the stake when the water has risen to a height just sufficient to spill over the weir. When the water has reached its full height, the depth above the bottom edge of the weir can be accurately measured by placing the end of a scale upon the top of the stake. If the measurement were made at the weir, it would be impossible to obtain an accurate result, owing to the curvature of the water as it flows over the edge.

In constructing a weir, it is important that the banks of the stream be parallel for a distance of several feet above it, and also that there be sufficient space at the sides, and sufficient depth below the notch, in order that the water may approach it quietly and without eddies.

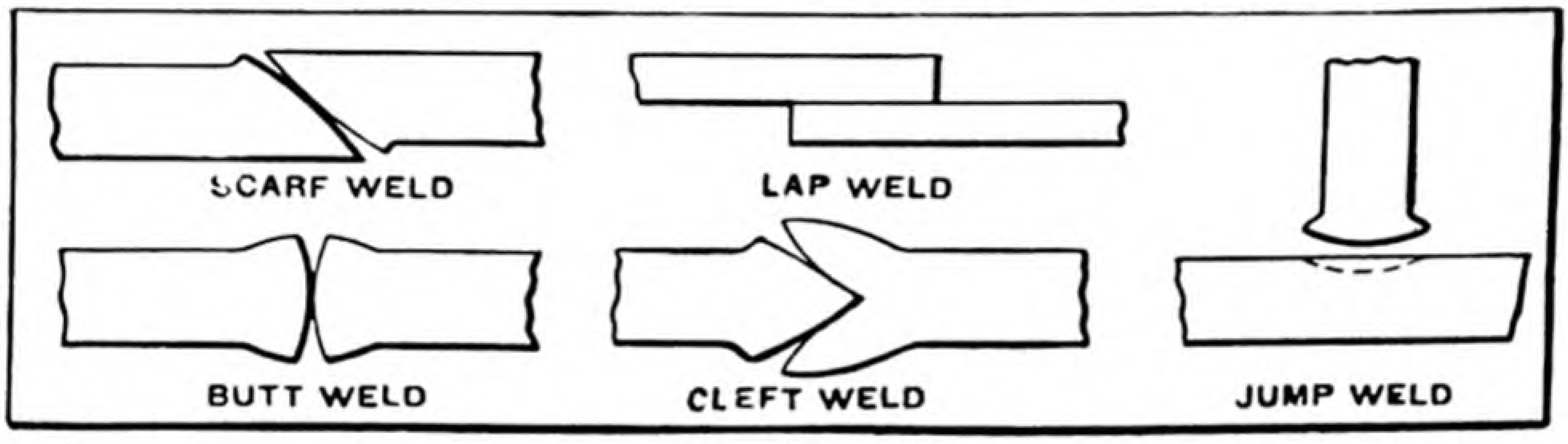
The following figures represent, in the order given, the depth of water flowing over the weir and the equivalent number of cubic feet of water per minute passing over the weir for each inch of its length A. Depth 1 inch, cubic feet per minute, 0.40; 2 inches, 1.14 cubic feet; 3 inches, 2.08 cubic feet; 4 inches, 3.20 cubic feet; 5 inches, 4.48 cubic feet; 6 inches, 5.89 cubic feet; 7 inches, 7.41 cubic feet; 8 inches, 9.07 cubic feet; 9 inches, 10.81 cubic feet; 10 inches, 12.66 cubic feet; 11 inches, 14.62 cubic feet; 12 inches, 16.65 cubic feet; 13 inches, 18.77 cubic feet; 14 inches, 20.99 cubic feet; 15 inches, 23.27 cubic feet; 16 inches, 25.62 cubic feet; 17 inches, 28.08 cubic feet; 18 inches, 30.59 cubic feet; 19 inches, 33.16 cubic feet; 20 inches, 35.84 cubic feet; 21 inches, 38.55 cubic feet; 22 inches, 41.32 cubic feet; 23 inches, 44.19 cubic feet; 24 inches, 47.09 cubic feet.

Example: Assume that a weir has a notch 120 inches in length and the depth of the water passing through it as measured at the stake is 20 inches. What is the flow of the stream? According to the figures previously given, a depth of 20 inches is equivalent to a flow of 35.84 cubic feet per inch of weir width. Since the total width equals 120 inches, the total flow equals $35.84 \times 120 = 4300$ cubic feet per minute.

WELDING. In ordinary forge welding two pieces of wrought iron or mild steel are heated until they become soft and plastic and will unite when one is pressed or hammered against the other. The quality of the weld depends largely upon the welding heat. If the ends to be welded are not hot enough, they will not stick together; inversely, if the work remains in the fire too long, it becomes overheated and burned, which greatly injures the metal. Iron which has been overheated has a rough, spongy appearance and is brittle. The danger of burning is increased when the air blast is too strong and the fire is oxidizing. It is important to heat the work slowly to secure a uniform temperature throughout the ends to be welded. With rapid heating, the outside may be raised to the welding temperature, while the interior is much below it; consequently, the weld will be defective.

Fire for Welding. — When heated iron comes into contact with the air, it absorbs oxygen, thus forming a scale or oxide of iron on the surface, which prevents the formation of a good weld. A fire for heating parts to be welded should have a fairly thick bed between the tuyere and the work, so that the oxygen in the air blast will be consumed before it reaches the parts being heated. When there is only a thin bed of fuel beneath the work, or if too strong a blast is used, the excess of oxygen will pass through and oxidize the iron. The hotter the iron, the greater the formation of scale. The surface being heated can be given an additional protection by covering it with some substance — flux — that will exclude the air. Ordinarily, the air blast for a forge fire should have a pressure varying from 3 to 5 ounces per square inch.

Classes of Welds. — Welds are classified according to the way in which the ends are formed prior to making the weld. The different welds ordinarily



Different Kinds of Welds

made in hand-forging practice are the scarf-weld, butt-weld, lap-weld, cleft- or split-weld, and jump-weld. (See illustration.) It will be seen that the surfaces, in most instances, are rounded or crowned. This is done so that, when the heated ends are brought together, they will unite first in the center. Any slag or dirt which may have adhered to the heated surfaces will then be forced out as the welding proceeds from the center outward. When making a lap-weld, the hammering should begin at the center in order to work out all the slag, as the faces in this case are not rounded. See also Atomic Hydrogen Welding; Autogenous Welding; Aluminum Welding; Electric Welding; Oxy-acetylene Welding; Thermit Welding.

WELDING FLUXES. In heating steel for welding, the tendency is for the surfaces to become oxidized, or covered with oxide of iron which forms a scale when the hot iron comes into contact with the air. If this scale is not removed, it will cause a defective weld. Wrought iron can be heated to a high enough temperature to melt this oxide so that the latter is forced out from between the surfaces by the hammer blows; but when welding machine steel, and especially tool steel, a temperature high enough to melt the oxide would burn the steel, and it is necessary to use a *flux*. This is a substance,

such as sand or borax, having a melting temperature below the welding temperature of the work, and it is sprinkled upon the heated ends when they have reached about a yellow heat. The flux serves two purposes: It melts and covers the heated surfaces, thus protecting them from oxidation, and, when molten, aids in dissolving any oxide that may have formed, the oxide melting at a lower temperature when combined with the flux. Wrought iron can be welded in a clean, well-kept fire without using a flux of any kind, except when the material is very thin. The fluxes commonly used are fine, clean sand and borax. When borax is used, it will give better results if burned. This can be done by heating it in a crucible until reduced to the liquid state. It should then be poured onto a flat surface to form a sheet; when cold, it can easily be broken up and pulverized. The borax powder can be used plain or it can be mixed with an equal quantity of fine clean sand and about 25 per cent of iron (not steel) filings. For tool steel, a flux made of 1 part of sal-ammoniac and 12 parts of borax is recommended.

WELD IRON. According to the definitions adopted by the Brussels Congress of the International Association for Testing Materials, held in 1906, the expression " weld iron " designates the same kind and quality of iron as wrought iron, but the term is considered obsolete and needless in engineering nomenclature.

WELDLESS CHAIN. This is a chain in which the links are not welded, but simply bent in such a way that each link hooks firmly into the preceding link.

WELD STEEL. This is iron containing enough carbon to harden if heated and suddenly cooled. The term " wrought steel " is also used.

WELLS PROCESS. The Wells process is a method for producing an oxide on iron or steel in order to protect it from the corrosive effects of the atmosphere. The process is similar in principle to the Bower-Barff process, except that the steam and producer gas enter the retort at the same time instead of being applied alternately. The result obtained by the Wells process is practically the same as that obtained by the Bower-Barff method.

WELSH METHOD. The English practice of smelting copper ores, known as the " Welsh method," is to roast the ores to remove the arsenic and antimony, and then smelt them in a blast or reverberatory furnace to a mixture of copper and iron sulphide known as " matte " or " coarse " metal. This matte is smelted in a blast or reverberatory furnace or in a converter to slag off the iron; the product is an impure copper sulphide, which is resmelted to form coarse copper, containing about 95 per cent of copper. This impure copper sulphide is known as " blue " metal, when some iron is present; " purple " metal, when copper and some copper oxide are

present; and "fine" or "white" metal, when it contains about 75 per cent of copper.

WESTON BRAKE. This is a mechanical brake where the braking action is created by the friction between a number of flat disks, and in which a spiral clutch or screw is used for automatically creating the required pressure between the disks.

WESTON CELL. The Weston cell is a primary cell or battery, known as a standard cell, used to obtain a certain standard value of electromotive force under given conditions. In this cell, the positive electrode is cadmium amalgam; the negative electrode, mercury; and the electrolyte, cadmium sulphate. This is a generally used standard cell. The electromotive force is 1.083 volt at 20 degrees C. (68 degrees F.).

WESTON METER. A Weston meter is an ampere-meter used for direct current only, in which a stationary permanent magnet acts upon a movable wire coil which is shunted by a low resistance.

WET-AIR COMPRESSION. This refers to the method of air compression in which a spray of water is injected into the cylinder in order to reduce the heat during compression. This method has long been abandoned.

WET-AIR PUMP. An air pump used for condenser service which handles both air and the water of condensation is known as a wet-air pump. It is extensively used in connection with steam engine condensers and other condensing apparatus.

WET CELL. A wet cell is a primary cell in which the electrolyte is in the form of a liquid.

WET STEAM. Wet steam is saturated steam which contains more or less moisture in the form of spray. The percentage of dry steam in steam containing moisture is called the quality of the steam.

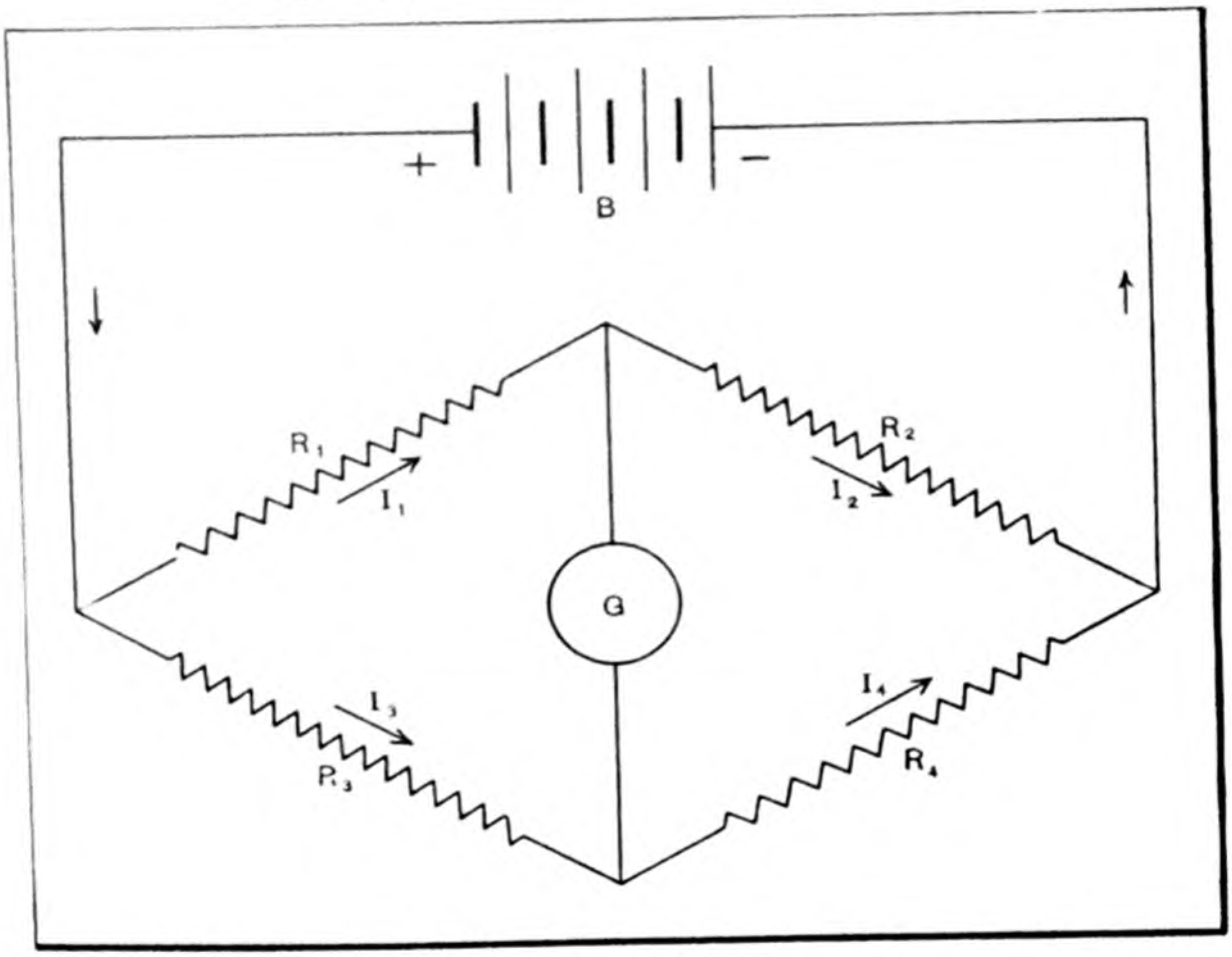
WHEATSTONE BRIDGE. The most generally used method for the measurement of the ohmic resistance of conductors is by the use of the *Wheatstone bridge.* In a simple form (see diagram) it comprises two resistance coils the ratio of the resistances of which is known, and a third, generally adjustable, resistance of known value. These are connected in circuit with the unknown resistance to be measured, a galvanometer, and a source of current, as in the diagram. The adjustable resistance and the "bridge arms," if necessary, are adjusted until the galvanometer indicates no flow of current. The value of the unknown resistance is thus measured, in terms of the known resistance and the known ratio of the bridge arms. In the diagram, R_1, R_2, R_3, and R_4 are resistances, B a source of electro-

motive force, and I_1, I_2, I_3, and I_4 currents through the resistances; G is a galvanometer. If the relation of the various resistances is such that no current flows through G, then I_1 equals I_2, and I_3 equals I_4; also I_1R_1 equals I_3R_3, and I_2R_2 equals I_4R_4, there being no electromotive forces in the triangles R_1R_3G and R_2R_4G. It follows, therefore, that

$$\frac{I_1}{I_3} = \frac{R_3}{R_1}, \quad \text{and} \quad \frac{I_2}{I_4} = \frac{R_4}{R_2},$$

and hence, as

$$\frac{I_1}{I_3} = \frac{I_2}{I_4}, \text{ it follows that } \frac{R_3}{R_1} = \frac{R_4}{R_2}.$$



Wheatstone Bridge

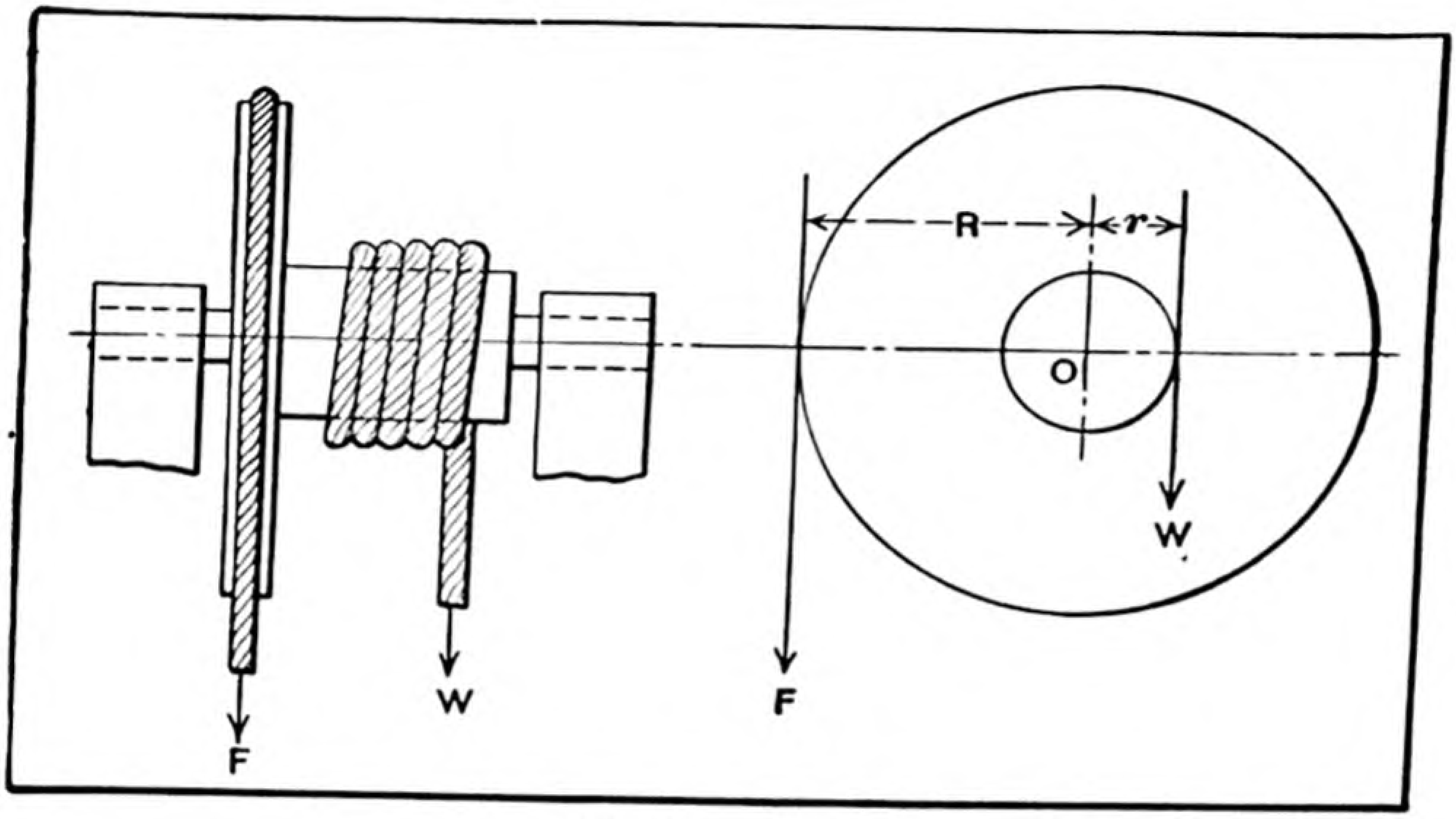
If one of these resistances, R_1, for instance, is unknown, it may then be found through the equation:

$$R_1 = \frac{R_2R_3}{R_4}.$$

Wheatstone bridges are made in many forms. The three known resistances are made adjustable and are usually made of many spools of special resistance wire. The resistances are usually varied by short-circuiting a greater or smaller number of these spools.

WHEEL AND AXLE. One of the so-called "mechanical powers" is known as the wheel and axle. It consists in its simplest form of a grooved

wheel, into which fits a cord, rope, or chain, and to which is rigidly attached a shaft or axle, from which a weight is suspended by means of another rope or chain, (see diagram). When sufficient pull is applied at F to overcome the resistance of the load attached at W, the weight will be raised. The principle involved is one of lever arms; the lever arm of force F is so much greater than that of weight W that the force F required to raise the weight can be proportionately smaller.



Wheel and Axle

Let R = radius of wheel at periphery of which force F acts, and r = radius of drum or axle at periphery of which weight W is applied. Then:

$$F : W = r : R.$$
$$F \times R = W \times r.$$

WHEEL CHUCK. Name applied to a work-holding chuck for machine tools, having a series of annular recesses or steps of various diameters for holding work which must be located very accurately with reference to its periphery. These chucks are generally used in bench lathes for work of larger diameter than could be held in a collet chuck.

WHEEL-TURNING LATHES. A "wheel lathe" is a special design used for turning locomotive driving wheels and car wheels after they have been pressed onto the axle. Lathes of this class are of duplex form, there being two driving heads and two tool-rests, so that both wheels may be turned simultaneously. One of the spindle driving heads is adjustable along the bed to allow for the variation in the length of axles having inside and outside journals. The toolposts are mounted on compound slides, so that the tools may be fed laterally or longitudinally. The large faceplates of these lathes are usually equipped with special driving dogs of powerful design, so that

deep cuts may be taken and coarse feeds used. In some shops, wheels are turned by broad forming tools which are fed straight in without any lateral feeding movement.

WHITE CAST IRON. White cast iron is a cast iron in which the carbon is present in the form of cementite or combined carbon, cementite being a carbide of iron, the chemical formula of which is Fe_3C. Carbon in chemical combination directly affects the properties of cast iron. White cast iron is hard, strong, and sound, but cannot be machined easily like gray cast iron.

WHITE COPPER. Same as Chinese copper. See Chinese Alloys.

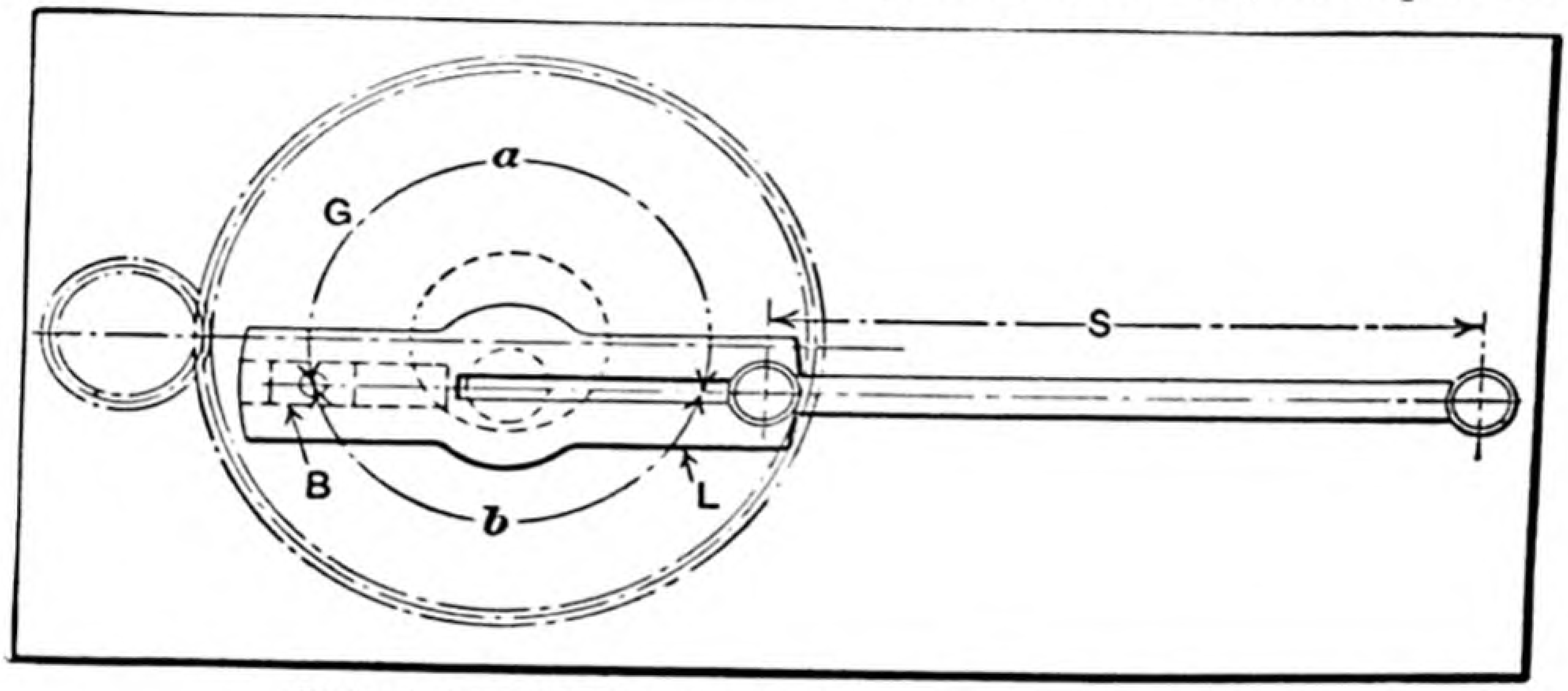
WHITE LEAD. Basic carbonate white lead is made in several ways. The old Dutch process consists in placing lead plates or grids in clay pots with dilute acetic acid, stacking the pots up, and covering with tanbark. Fermentation of the latter causes a rise in temperature and the production of carbon dioxide, which acts on the lead in the pots and gives a basic lead carbonate. At the end of two months, the white lead is ground in water, and dried, being ground later in oil. The "quick process" requires but two weeks, and is carried out by the action of dilute acetic acid and carbon dioxide on finely divided lead, in revolving cylinders. In the "mild process" no acid is used, the finely divided lead being agitated in water through which air is blown. Hydrate of lead is formed, and later carbonated. A very good product, free from all acid, is thus obtained. The result of all of these methods is a very valuable pigment with a specific gravity of 6.8, grinding in 9 per cent of oil. It is very opaque and has much body, but is rather low in spreading power and is generally mixed with zinc oxide or pigments of similar nature. Sulphurous gases blacken it easily, and it has a great tendency to chalk, due to the fact that it is naturally alkaline and thus acts on the linseed oil in the paint. It is generally inhibitive in its action and is widely used.

WHITE METAL. The term "white metal" is applied to a number of alloys containing mainly zinc and tin, or lead, tin, and zinc. White metals are used for bearings on railroad cars, generators, motors, etc. The composition of one of these white metals used as a bearing metal is as follows: Lead, 33 per cent; tin, 54 per cent; antimony, 10.6 per cent; and copper, 2.4 per cent. White metal made according to the specifications of the United States Navy Department consists of 88.8 per cent of Banca tin; 3.7 per cent of best refined copper; and 7.5 per cent of regulus of antimony, well fluxed with borax and rosin in mixing. Several English railways use from 73 to 77 per cent of tin; from 15 to 19 per cent of antimony; and from 7 to 9 per cent of copper. White metal is sometimes used as a pattern material, especially when it is necessary to avoid shrinkage. The addition of antimony makes the metal almost entirely free from shrinkage upon cooling.

WHITE NICKEL BRASS. See Brass Alloys for Castings.

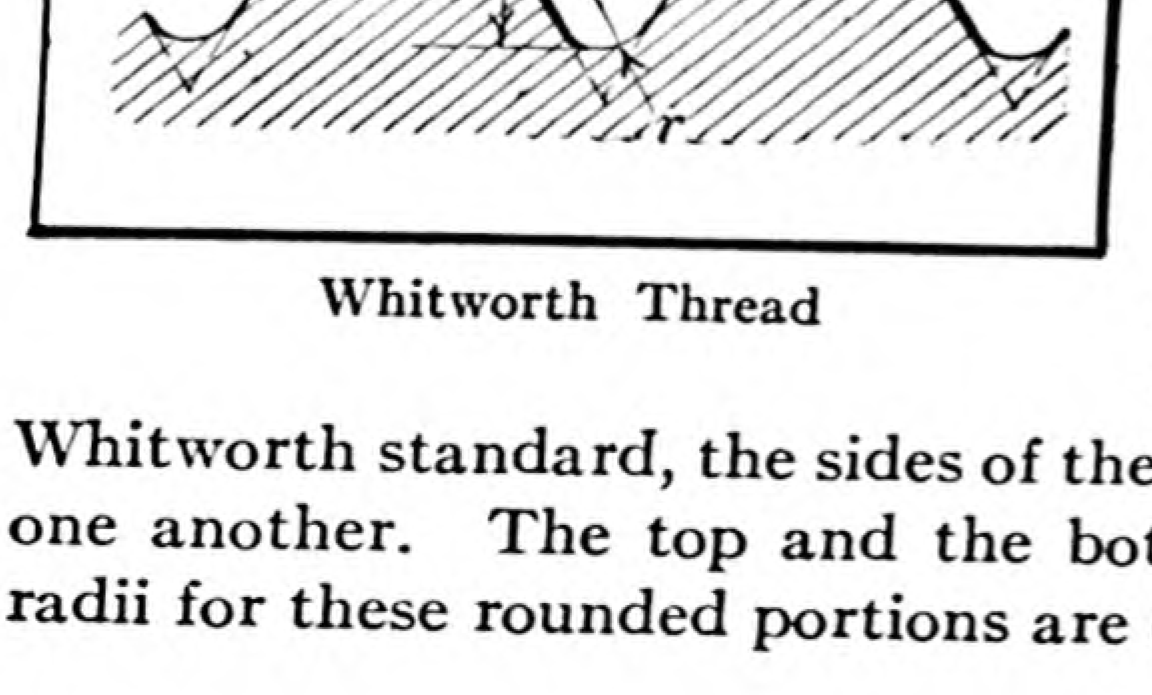
WHITING. Calcium carbonate, or whiting, found extensively as chalk, is used to a considerable extent in paints partly on account of its power of neutralizing any free acid in the linseed oil. See Calcium Carbonate.

WHITWORTH MOTION. A quick-return motion that has been widely used in slotter construction, and on certain classes of shapers and other tools, is illustrated by the diagram. This mechanism is known as the "Whitworth motion." The gear *G* drives a slotted link *L*, which is pivoted at some point within the path of the crankpin or block *B*, thus permitting the



Principle of Whitworth Quick-return Motion

link to rotate through a complete revolution. As the center about which link *L* rotates is offset with relation to the center of the driving gear *G*, the driving pin *B* moves through an arc *a* during the cutting stroke, and through a shorter arc *b* for the return stroke, which, therefore, requires less time, in proportion to the respective lengths of arcs *a* and *b*. This mechanism, when incorporated in the driving mechanism of a machine like a slotter, serves to return the ram and tool quickly after the cutting stroke, thus reducing the time for the idle or non-cutting period.



Whitworth Thread

WHITWORTH STANDARD THREAD. The Whitworth standard thread, also known as British Standard Whitworth (B. S. W.), is used principally in Great Britain, but also to some extent in the United States. In the Whitworth standard, the sides of the thread form an angle of 55 degrees with one another. The top and the bottom of the thread are rounded. The radii for these rounded portions are determined by the depth of the thread,

which is two-thirds of the depth of a thread of the same angle, sharp at the top and bottom. The radii at the top and at the bottom are the same. If p = pitch of thread, d = depth of thread, and r = radius at top and bottom of thread, then:

$$d = \frac{2}{3} \times \frac{p}{2} \times \cot 27 \text{ deg. } 30 \text{ min.} = 0.6403\, p = \frac{0.6403}{\text{No. Th'ds. per inch}}.$$

$$r = 0.1373\, p = \frac{0.1373}{\text{number of threads per inch}}.$$

As the Whitworth thread is rounded at the root and crest, there are no sharp edges or corners from which fractures may start. Screws and nuts having this form of thread will also work well together after continued heavy service. In the United States, Whitworth threads have been used on special screws and on a great many staybolts for the fire-boxes of locomotive boilers. A series of tests have indicated that the Whitworth thread is somewhat stronger than the U. S. standard form.

WHITWORTH THREAD ORIGIN. The work of the earlier generation of English tool builders culminated in that of Sir Joseph Whitworth. He, like most other English mechanics, was a North-country man, who had worked for both Maudslay and Clement. The succession of influence running through these men is singularly illustrated in the development of standard screw threads. Maudslay standardized the screw-thread practice of his own shop, settling upon and adhering to a definite number and size of threads for each size of screw then in use. Clement, who worked for Maudslay, adopted these standards, improved them, began the manufacture of taps and dies, and invented the tap having a small shank to enable it to fall through the tapped hole, thereby avoiding the necessity for backing out the tap. Whitworth took up the work of Clement and Maudslay, and, after making a careful study of all the threads in general use, proposed, in a paper before the Institute of Civil Engineers in 1841, the standard which became general throughout Great Britain and continues today as the Whitworth standard thread. Most of the general tools had been invented by the time Whitworth began his independent work, but he so improved their design and workmanship that he influenced English tool practice for several generations. He introduced an accuracy in commercial work unknown until that time, which was made possible by his improvements in the methods of measurement.

WICK OILING. A method of supplying lubricant to a bearing by using a wick one end of which is submerged in oil, the other end leading to the bearing.

WILLIAMS INTERNAL GEAR. See Internal Gear, Williams.

WILLOW CHARCOAL. Willow charcoal, used in the making of paints, is made by charring certain kinds of wood, and contains a slight amount of alkali, which is probably the cause of its good inhibitive powers. It is a light pigment, and grinds to a paste in 33 per cent of oil.

WINCHESTER BUSHEL. A measure of capacity or volume, legal in the United States, and equal to 2150.42 cubic inches. This measure has not been legal in Great Britain since 1825, when it was superseded by the Imperial bushel which is equal to 2218.19 cubic inches.

WINDMILL POWER. The power of windmills of the same type varies approximately as the square of the wheel diameter, and as the cube of the

TABLE 1

Size of Mill, Feet	5 Miles	10 Miles	15 Miles	20 Miles	30 Miles	40 Miles
8	0.011	0.09	0.29	0.7	2.1	......
12	0.025	0.20	0.67	1.6	5.4	12.8
16	0.045	0.36	1.21	2.8	9.7	21.0

TABLE 2

Size of Mill, Feet	10 Miles	15 Miles	20 Miles
12	0.21	0.58	1.05
16	0.29	0.82	1.55

wind velocity. This general rule is based on the theory that the intercepted area of air current varies as the square of the wheel diameter, and that the kinetic energy of the air, impinging on such an intercepted area, varies as the cube of the wind velocity. This rule is applicable within reasonable limits, but as windmills are designed to give the best efficiency in low winds, say, from 10 to 15 miles per hour, the same angle of sail will not give the same percentage of efficiency in winds of considerably higher velocity.

The ordinary wheel works most efficiently under wind velocities of from 10 to 12 miles per hour. Such wheels will give reasonable efficiency in from five- to six-mile winds. Mills built for grinding purposes, geared mills, or power mills as they are called, when attached to a grinder having a centrifugal feed, will develop power almost proportional to the cube of the wind velocity, within reasonable limits of such velocity, as their speed need not

be kept down to a certain number of revolutions per minute, as in the case of a pumping mill. Should this theoretical condition hold, Table 1, showing the amount of power for different sizes of mills at different wind velocities, would apply. The figures which show the horsepower, have been proved by laboratory tests. The results of tests on mills actually in use are given in Table 2, the figures indicating the horsepower.

The foregoing tables must be translated with reasonable allowance for conditions under which wind wheels must work, and which cannot well be avoided; pumping mills must be made to " regulate off " at a certain maximum speed to prevent damage to the attached pumping devices. The regulating point is usually between 20- and 25-mile wind velocities, so that no matter how much higher the wind velocity may be, the power absorbed and delivered by the wheel will be no greater than that indicated at the regulating point.

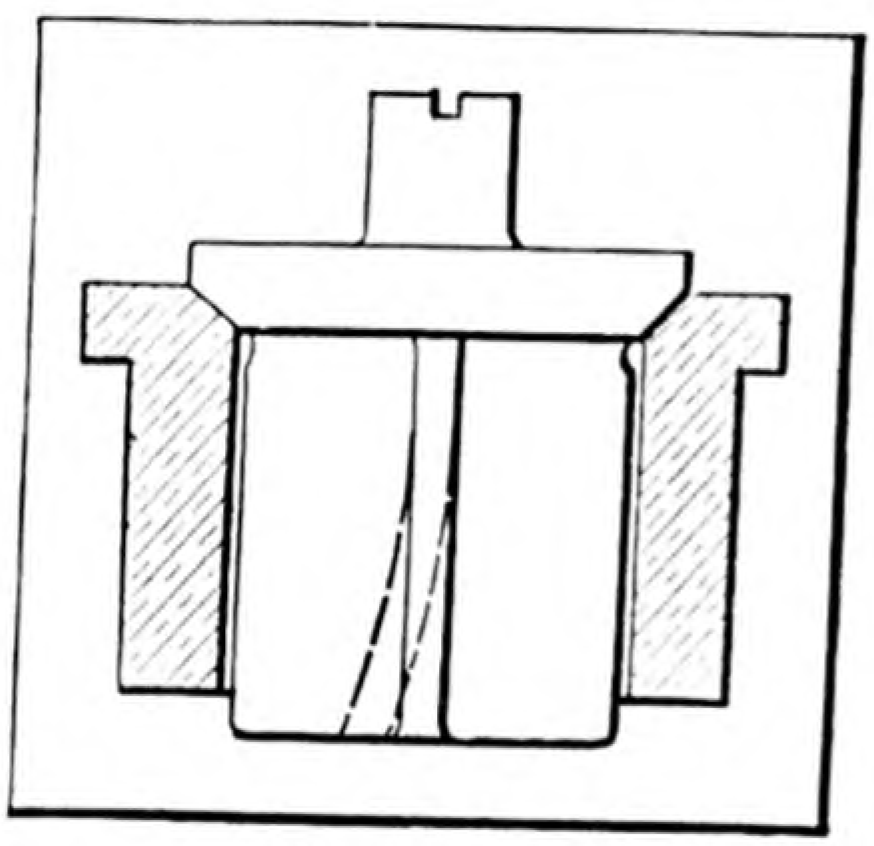
WINDMILL REQUIREMENTS. A well-designed windmill must work satisfactorily in a light wind. A mill that requires a ten-mile wind may run only four or five hours per day; a mill that will run in a five-mile wind will probably run eighteen hours per day in some localities. Experiments developed the fact that seven-eighths of the zone of interruption could be covered with sails; that more than this was detrimental, and that the gain in power in from three-fourths to seven-eighths of the surface was so small that the use of the additional material was not justified; that the sail surface should extend only two-thirds the distance from the outer diameter to the center; that a wheel running behind the carrying mast is not nearly as efficient as one running in front of the mast; that there should be the least possible obstruction behind the wheel; that to be efficient the velocity of the travel of the circumference of the wheel should be from 1 to $1\frac{1}{4}$ times the velocity of the wind, hence the necessity of back gearing to reduce the pump speed to forty strokes per minute as a maximum. The requirements for the installation of a successful windmill electric plant are stated in a concise form as follows: Ascertain first the average daily load in ampere-hours during the periods of maximum current consumption. Then provide a storage battery for a capacity at least double this output, install a generator of sufficient capacity to charge this battery for 12 hours, and lastly select a windmill sufficiently large to run the generator at full load with a 10-mile per hour wind. Fit the windmill and driving gear to the generator by ball or roller bearings throughout, so as to, as far as possible, eliminate frictional loss.

The wood wheel, as generally constructed, is inefficient and short-lived, and designed without reference to the principles of wind dynamics. Actual test have shown that some wood wheels, under certain wind conditions, will

give more power with every alternate slat removed, and on wood wheels having slats ½ inch thick and 3 inches wide, the efficiency of the wheel is reduced nearly one-sixth, merely from the action of the wind on the edge of the slat. Steel sails are much more efficient than wood.

WIND PRESSURES. Wind pressures per square foot for different wind velocities in miles per hour are as follows: Fresh breeze of 10 miles per hour, pressure 0.4 pound; stiff breeze of 20 miles per hour, pressure 1.6 pounds; strong wind of 30 miles per hour, pressure 3.6 pounds; high wind of 40 miles per hour, pressure 6.4 pounds; storm with velocity of 50 miles per hour, pressure 10 pounds; violent storm with velocity of 60 miles per hour, pressure 14.4 pounds; hurricane with velocity of 80 miles per hour, pressure 25.6 pounds; violent hurricane with velocity of 100 miles per hour, pressure 40 pounds per square foot. The foregoing figures are based on data obtained by the U. S. Signal Service at Mt. Washington, N. H.

WING VALVES. A wing valve is so called because it is guided in its vertical movement by wings which extend down below the valve-seat. The wings of some valves are curved slightly (as shown by the dotted lines of the accompanying sketch) so that the valve will automatically rotate part of a revolution each time the liquid is forced through it. The object of designing the valve to secure this turning movement is to wear both the valve and seat more evenly. In order to avoid obstructing the valve port, some valves are guided by a stem which enters a bonnet above the valve. With such an arrangement, the stem should be fluted or other provision made to prevent the formation of a partial vacuum above the valve stem, as this would delay the return of the valve to its seat.



Wing Valve

WIPED JOINT. A form of joint known as a "wiped joint" is made by plumbers in the following manner: The parts to be joined are first tinned at the points of contact to remove the oxide, and then firmly placed and secured in position. Molten solder is poured upon the desired place, and the joint is wiped by hand with a moleskin or cloth pad while the metal is in a plastic condition.

WIPING SOLDER. Plumbers' solder, or *wiping solder*, as it is commonly called, is composed of 40 per cent of tin and 60 per cent of lead. At certain temperatures, it takes the form of a pliable mass, allowing it to be easily

handled and molded to produce the characteristic form of plumbers' wiped joint.

WIRE DRAWING. Wire drawing is the process used for producing wire of smaller diameter by drawing a wire or rod of larger diameter through a plate or die provided with a hole which reduces the size to the desired dimension. Briefly described, the machines used for wire drawing consist of a die or " draw-plate " provided with holes through which the wire is drawn, and means for pulling the wire through these dies and winding it upon a reel. The draw-plate or die for larger sizes of wire is generally made from chilled cast iron or steel, but for the finer sizes it is made from one of the less expensive or imperfect varieties of diamond, because diamond dies can be used for a longer period without losing their size. When the wire is drawn through the holes in the dies, thus reducing its diameter, the drawing action hardens the wire and makes it brittle. It must, therefore, be annealed at frequent intervals, before it is further reduced to a smaller size by a subsequent drawing operation. Oil, tallow, and soap water are used to lubricate the dies. Another method is to immerse the wire in a sulphate of copper solution. A film of copper is thus deposited, which provides some lubrication, making the drawing operation much easier. In some cases, when iron and steel wire is treated in this way, the copper is left on the wire after the final drawing to serve as a rust preventative. The first wire-drawing mill in America was built in 1775, in Norwich, Conn., by Nathaniel Niles, who was granted a loan of $1500 by the court for this purpose. Previous to the development of wire drawing, wire was made by hammering or beating metal into thin sheets or plates, which were cut into continuous strips. These strips were then afterwards rounded by hammering.

WIRE FEED. The name wire feed is often applied to the mechanism for feeding a rod through the spindle of a screw machine. The term " wire-feed screw machine " is sometimes used to indicate a design having a mechanism for automatically feeding the stock through the spindle, whereas a machine not having this stock-feeding mechanism may be designated as a *plain screw* machine.

WIRE FORMING. Nearly every conceivable shape can be produced in wire by the use of a wire-forming machine, supplemented in some instances, particularly where ribbon stock is to be formed, by the power press. The various machines in common use are designed to operate practically in the same manner. They consist fundamentally of four cam-operated slides arranged 90 degrees apart; these advance to a common center at which point a vertical member, called the " king-post," is located. The king-post is the member around which the wire is shaped by the dies or forming mem-

bers that are carried in the slides. Obviously, the range of service of the machine depends upon the ingenuity employed in laying out suitable cams and in setting up the job. Considerable variation from the four-slide arrangement is practicable, because it is possible to mount auxiliary cams on each camshaft for operating levers and additional slides, so that pieces requiring more than four bending operations can be produced by thus increasing the scope of the machine.

The forming dies are simple in construction, and consist of finger members attached to the slides, usually provided with a groove at the end to receive and guide the wire as it is bent. Auxiliary levers are frequently interposed between the slides when extra bending members are required, and these are essentially of the same design as the dies except that they usually move independently of the slides. The movements necessary to form a piece of wire into a more or less complicated shape may be varied in their sequence. The first consideration when a part is to be manufactured is the proper starting place in relation to subsequent operations. It has been found, even after large quantities of pieces have been manufactured commercially by one method, that greater production can be obtained by making certain simple changes which affect the entire cycle of the movements and completely revise the manufacturing procedure.

WIRE GAGES. See Gages for Wire.

WIRELESS BEAM REFLECTOR. A wireless beam reflector is an instrument for directing radio waves with increased intensity in a certain direction. The principle on which it is built is based on the fact that the electro-magnetic waves employed in radio transmission obey all the known laws of light. A parabolic reflecting surface is built up of tuned wires, and the transmitter aerial, which is placed at the focus, takes the form of a plain suspended wire of half wave length dimension. The size of the reflector is slightly over 30 feet from the center to the extremity of each of the four arms of which it is built up.

WIRELESS TELEGRAPH. The development of wireless telegraphy was due to the work of several men, including Heinrich Hertz, a German scientist; Tesla in the United States; Branly and Ducretet of France; Popoff of Russia; Prof. Lodge of England; and Righi and Marconi of Italy. In 1899 Marconi, as the result of his developments, succeeded in communicating between points in England and France for a distance of 32 miles across the English Channel.

WIRE, PLOW STEEL. See Plow Steel Wire.

WIRE ROD. Rolled bars of small diameter, especially those intended to form the raw material for wire drawing, are known as *wire rod.* This prod-

uct is produced by hot-rolling in a wire mill. Two different principles are embodied in the design of rolling mills used for producing wire rod. In the one, the *Belgian* or *looping* mill, the wire rod is bent as it comes through the first rolls, and started in the return pass at once. From the second pass, the wire rod is bent or looped back again into the third pass, and so on. This method can be used after wire rods have been reduced to $\frac{3}{4}$ inch in diameter, and the reductions which the rod may pass through in this way may be any number up to six or seven. The speed of all the rolls is often alike, and the material, due to the elongation in the rolling process, occupies a larger space on the floor between any two succeeding passes than between the preceding ones. As the wire emerges from the last pass, it is wound up on a power-driven reel. In an improved form of this type of mill, the roughing train is detached from the remainder of the mill and driven separately at a slower speed, thus increasing the production. A fair production is twenty-five tons of wire rod of about 0.200 inch in diameter.

In the *continuous* type of mill, a stand of rolls is provided for each reduction, the stands being placed one after the other and close together, so that the rod moves in a straight line through the entire mill without handling. Each alternate pair of rolls is placed in a vertical position, so that the rod is reduced alternately in a vertical and horizontal plane. To prevent the wire from looping or kinking between the rolls, each successive stand of rolls is run at such a speed as to exactly compensate for the elongation consequent to the reduction of the rod in the previous pass. The rolls are placed close together in order not to expose the hot metal to the air more than is necessary. By means of the continuous process of wire-rod rolling, it is possible for one end of the billet to be in the furnace while part of it passes through the mill and the other end is wound upon the reel. The looping and the continuous principle have also been combined into one mill. A continuous roughing mill is used for breaking down the billet to looping sizes, and then a looping mill, made in sections — usually three — is employed for rolling the wire to the required size. Each section of the looping mill is driven from a separate shaft at a different speed, the finishing rolls running at 500 or more revolutions per minute.

WIRE ROPE. Wire ropes are made by twisting a number of wires together into a strand, and then twisting a number of strands about a hemp core to form a wire rope. Sometimes the hemp center is replaced by a wire strand which adds from 7 to 10 per cent to the strength of the rope. The strand is usually made by placing one wire in the center and surrounding this with a layer of 6 wires, thus forming a 7-wire strand. If another layer of wires is placed outside of this layer, this new layer will contain 12 wires, and the strand will be a 19-wire strand. An additional layer will contain 18 wires, thus making a 37-wire strand. By adding another layer, this time

of 24 wires, a 61-wire strand is obtained; and, in exceptional cases, still another layer may be added, this time of 30 wires, making a 91-wire strand.

The advantages of wire rope as compared with hemp rope are as follows: Greater strength for the same diameter; greater strength for the same weight; lower cost for the same strength; equal strength whether wet or dry (a hemp rope may lose as much as 30 per cent of its strength when wet); equal length under all weather conditions; greater indestructibility; and greater variety in types of construction that may be applied to different uses. As another advantage may also be mentioned the greater certainty with which the strength of wire ropes may be computed.

Types of Wire Rope. — When all the wires used in making a strand are of the same size, the construction is known as a *one-size-wire* type. Another construction, known as the *Warrington* type, or *three-size-wire* construction, makes use of 7 wires of uniform diameter surrounded by a layer of 12 wires of which 6 are large and alternate with 6 smaller wires. The Warrington construction increases the metallic area and, hence, the strength for a given outside diameter of rope by approximately 10 per cent, and is advantageous for general hoisting purposes. Still a third type of construction, known as the *Seale* type, is used. In this, the center wire is large; then there is a layer of 9 small wires, and then an outer layer of 9 large wires. Strands made in this manner will produce a rope which is somewhat stiffer than the ropes made by one-size-wire or three-size-wire construction.

Wire ropes are made from a number of different materials varying from iron wire to the highest grade of special steels. Iron was used almost entirely for wire ropes in the early days of wire rope manufacture. At the present time, it is employed only to a limited extent. Compared with newer materials, it is of a low tensile strength and soft, and although ductile and pliable, it is heaviest in proportion to its strength.

Crucible-steel Wire Rope. — Crucible steel is a tough and pliable material of moderate cost when used for wire ropes. It has about double the strength of iron for the same weight; it is also harder than iron, and, therefore, resists external wear better. The steel has derived its name from the early method of making high carbon steel in small crucibles, but the same grade of steel for wire rope is now made by the Siemens-Martin open-hearth process. When drawn into wire, steel of this quality will have an ultimate strength of from 150,000 to 250,000 pounds per square inch, the higher figure applying to the finer wires and the lower to those of larger diameter.

Plow-steel Wire Rope. — The name "plow" steel originated in England and was applied to a strong grade of steel wire used in the construction of very strong ropes employed in the mechanical operation of plows. The name "plow" steel, however, has become a commercial trade name, and, applied to wire, simply means a high-grade open-hearth steel of a tensile

strength in wire of from 200,000 to 260,000 pounds per square inch of sectional area. A strength of 200,000 pounds per square inch is obtained in wire about 0.200 inch in diameter. Plow steel when used for wire ropes has the advantage of combining lightness and great strength. It is a tough material, but not as pliable as crucible steel. The very highest grade of steel wire used for wire rope is made from special steels ranging in tensile strength in wire from 220,000 to 280,000 pounds per square inch of sectional area. This steel is especially useful when great strength, lightness, and abrasive resisting qualities are required.

Galvanized Wire Rope. — The following information on materials used for wire rope and the practical applications of different materials is from the United States Government specifications: Galvanized wire rope should be used if the rope is likely to corrode because of the presence of moisture, as for the standing rigging of a ship. Because the zinc coating is rapidly removed by wear, it should not, in general, be used for hoisting. It may, however, be used for the running rigging and for wheel (steering) ropes on ships, as these ropes do not wear rapidly.

Uncoated Wire Rope. — Uncoated wire rope should be used where it is protected from moisture, as in a building, and for more or less continuous hoisting. It may be used instead of galvanized wire rope where it is exposed to moisture, as for derrick guys, if a protective coating is applied to the rope at regular intervals.

Phosphor-bronze Wire Rope. — Phosphor-bronze wire rope has lower strength than steel wire rope; therefore, the working loads should be lower. The sheaves should also be larger than those for steel rope. It is non-magnetic, and can be used for conditions under which galvanized steel rope does not give satisfaction. Because of these properties, it is used on small vessels.

Marline-covered Wire Rope. — Marline-covered wire rope is stronger and more durable than manila rope. The marline covering prevents wearing of the wires and supplies lubricant to them. As the marline wears to a smooth surface, the rope is easily handled or laid in a flat coil. Compared with uncovered wire rope, the marline-covered rope is more easily handled, has greater friction, which is an advantage if it is used on a smooth drum, and is more durable, particularly if it is exposed to gases, grit, or moisture.

WIRE ROPE DEFINITIONS. In the following are given brief definitions of commonly used terms met with in the application of wire rope.

Airplane Strand. — A small 7- or 19-wire galvanized strand made from plow steel or crucible steel wire.

Cable Laid Rope. — A compound laid rope consisting of several ropes or several layers of strands laid together into one rope, as, for instance, 6 by 6 by 7.

Crane Rope. — Wire rope consisting of 6-strands of 37 wires around a hemp center.

Elevator Rope. — Wire rope usually made of iron and composed of 6 strands of 19 wires each, and a hemp core.

Extra-flexible Hoisting Rope. — A rope consisting of 8 strands of 19 wires each with a large hemp center.

Flat rope. — A rope consisting of alternate right and left lay rope strands, each rope strand consisting of 4 strands of 7 wires, all sewed together with a number of soft iron sewing wires.

Flattened Strand Rope. — A wire rope having non-cylindrical strands, usually of the oval or triangular type; the center wire of each strand is an oval or a triangular wire.

Guy Rope. — Galvanized rope consisting of 6 strands, 7 wires each, and a hemp core.

Guy Strand. — Galvanized 7-wire strand.

Hand Rope. — Flexible rope consisting of 6 ropes, each composed of 6 strands, 7 wires each, and 7 hemp cores.

Haulage Rope. — Rope usually composed of 6 strands, 7 wires each, and a hemp core.

Hawser. — Wire rope usually consisting of 6 strands, 37 wires, and a hemp core, or 6 strands, 24 wires, and 7 hemp cores.

Hoisting Rope. — Rope consisting of 6 strands of 19 wires each, with a hemp center.

Lang Lay Rope. — Wire rope in which both the wires in the strand and the strands in the rope are twisted in the same direction.

Left-lay Rope. — Wire rope, the strands of which form a left-hand helix like a left-hand screw thread.

Left Twist. — Same as right lay, and corresponds to a right-hand screw thread.

Lay. — The pitch or angle of the helix of the wires or strands of a rope, usually expressed by the ratio of the diameter of the strand or rope to the length required for one complete twist.

Non-spinning Rope. — A rope wire consisting of 18 strands of 7 wires each, in two layers; the inner layer consists of 6 strands Lang lay and left lay around a small hemp core, and the outer of 12 strands regular lay, right-hand lay. Will carry a load on a single end without untwisting.

Regular Lay. — Strands twisted to the right and rope twisted to the left. Helix of strands takes the direction of a right-hand screw thread.

Reverse Laid Rope. — A wire rope with alternate strands right and left lay.

Rheostat Rope. — A small rope consisting of 8 strands of 7 wires each.

Right Lay. — Known also as regular lay; strands twisted to the right and rope twisted to the left; corresponds to a right-hand screw thread.

Right Twist. — Corresponds to left lay, or to a left-hand screw thread.

Running Rope. — A flexible rope of 6 strands, 12 wires each, and 7 hemp cores.

Special Flexible Hoisting Rope. — A wire rope consisting of 6 strands, of 37 wires each, and a hemp core.

Standing Rope. — Another term applied to galvanized guy rope which consists of 6 strands, 7 wires, and a hemp core.

Towing Hawser. — A large flexible wire rope made of galvanized wires. Usual construction, 6 strands of 37 wires each, or 6 strands of 24 wires each.

Transmission Rope. — Rope composed of 6 strands, 7 wires each, and a hemp core.

WIRE ROPE DRUMS. The drums used for wire ropes should be grooved rather than flat. The grooves should be so spaced on the drum that there is ample clearance between the successive windings on the drum. For example, a drum for a 1-inch rope should have the centers of the grooves at least $1\frac{1}{16}$ inches apart. If the groove is made in this manner, the successive convolutions of the rope will not rub against each other. The grooves of all sheaves and drums for wire rope should be smooth, so that they do not cause abrasion to the rope wound upon them. The grooves should also be of a slightly larger radius than the radius of the rope, so that there will be no wedging or pinching action. If possible, the drum upon which a wire rope is wound should be wide enough so that the rope may be wound upon it in one layer. It is bad practice to wind the rope upon the drum several layers deep. The respective layers of the rope will wear against each other and the life of the rope will be considerably shortened. When there is not space enough for a large drum, flat wire ropes, which may be wound in successive layers, are often used.

WIRE ROPE, FLAT. See Flat Rope.

WIRE ROPE LAY. See Lay of Wire Rope.

WIRE ROPE LUBRICATION. Practically all the cores of good brands of wire rope are thoroughly impregnated with a commercial, chemically neutral rope oil. While the core retains a liberal supply of this lubricant, frequent application of a good lubricant during service, to prevent the core from becoming dry, is advisable. A dry core will both wear and crush quicker than an oil-impregnated core and it will absorb moisture, with the result that the core will deteriorate rapidly and the inner wires will corrode, thus shortening the rope service. The smaller the sheaves or the heavier

the tension on the rope, the more often should the rope be lubricated. A good lubricant retards corrosion of the wires and deterioration of the core, reduces internal friction which is the cause of wires breaking from bending stresses, and decreases external wear. The lubricant should be thin enough to penetrate the strands and the core, but not so thin as to run off the rope, nor so thick that it merely covers the rope. Therefore, semi-plastic compound applied hot (in a thinned condition) is the best wherever possible. It will penetrate while hot, then cool to a plastic filler, excluding the entrance of water, and both preserving and lubricating the inner wires and cores. To lubricate properly with a heated lubricant, it is necessary to have the rope run slowly through a tank of heated oil.

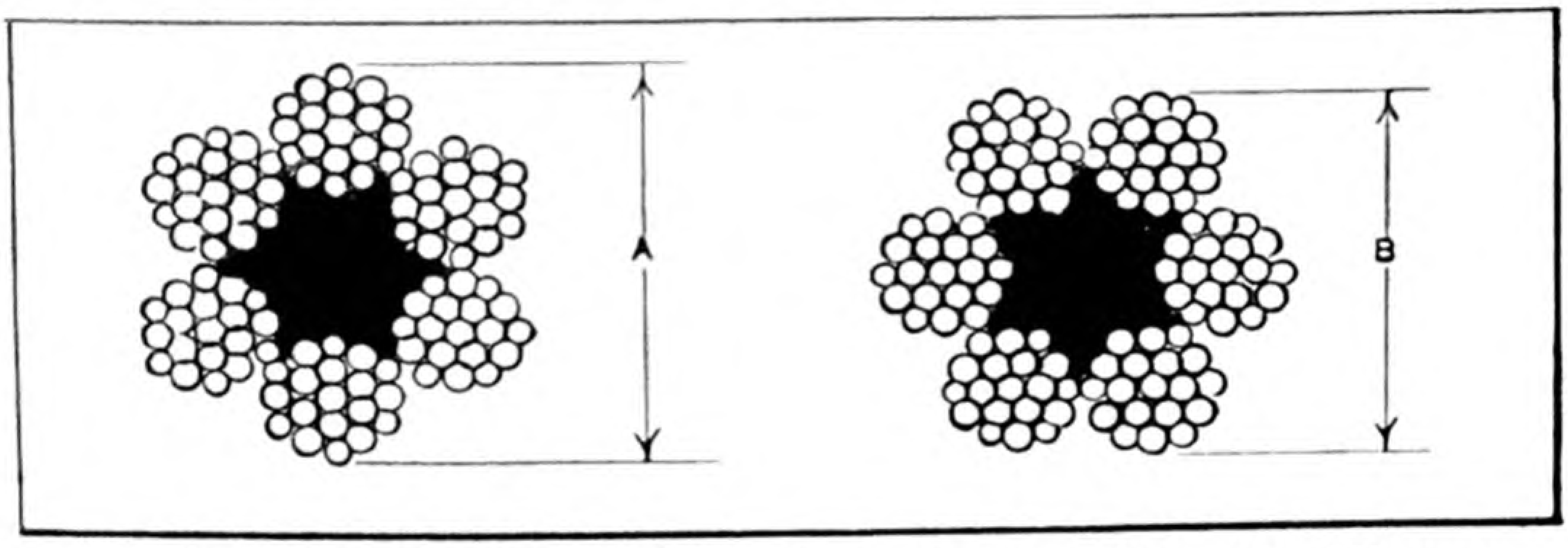
Government Specifications. — The following information on the lubrication of wire rope is taken from the United States Government specifications for wire rope: Wear of a running wire rope occurs where the outside wires come into contact with the sheaves and drums, especially if slipping takes place, and, also, where the inner wires of the rope are in contact. During the fabrication of a wire rope, the fiber core is saturated with lubricating compound, which in service is gradually supplied to the wires and reduces the wear on them. As the core will not carry enough lubricant for the life of the rope, it is necessary occasionally to apply a lubricant to the outside of the rope, which will be absorbed by the core. A mixture of a heavy-bodied lubricant and a good grade of graphite is as satisfactory as any of the proprietary lubricants, and is cheaper. A viscous preparation which remains on the outside of the rope does not lubricate the inner wires of the rope.

For elevator cables, any lubricant containing an opaque substance is undesirable, as it interferes with the proper inspection of the rope by making it difficult to detect broken wires. Graphite and similar lubricants may cause excessive sliding of cables on traction-drive elevators, and should not be used on this type of equipment. Boiled linseed oil, applied hot, will saturate the hemp center and will give a transparent covering when dry that will not interfere with the thorough inspection of the rope. If an uncoated wire rope is to be used where it is likely to corrode, the lubricant should have a very heavy body and be applied to the rope so hot that it will penetrate to the core.

WIRE ROPE MEASUREMENT. The correct way to measure wire rope, is shown at *A* in contrast to the incorrect method as at *B* in the illustration on page 1219. It is important that the proper size of rope be employed, since an under-sized rope will not give the degree of service that should reasonably be expected, while an over-sized rope represents needless investment.

WIRE ROPE TESTS. Experiments made at the Bureau of Standards indicate that a six-strand, nineteen-wire, plow-steel, $\frac{5}{8}$-inch wire rope, when bent over a 10-inch sheave, loses 12.6 per cent of the strength that it has when straight, and when bent over an 18-inch sheave, 4.7 per cent. A $1\frac{1}{4}$-inch rope loses 24.2 per cent, when bent over a 10-inch sheave, and 15.3 per cent on an 18-inch sheave. The wires of which the ropes were composed had a strength of 230,000 pounds per square inch, and the strength of the rope itself, when straight, equaled $83{,}000d^2$, in which d is the diameter of the rope in inches. The modulus of elasticity of steel wire rope may be assumed to be about 8,500,000.

WIRE ROPE UNCOILING. Wire rope is ordinarily shipped and received either in coils or on reels. In uncoiling or unreeling wire rope, it is essential that no kinks be allowed to form. Once a kink is made, no amount



(A) Correct and (B) Incorrect Methods of Measuring Wire Rope Diameter

of twisting or strain can take it out, and the rope is unsafe for work. Never uncoil a wire rope as you would a rubber hose or manila hemp rope. Place the coil on its edge and unroll the coil, allowing the rope to lie flat until used.

WIRE STRAIGHTENERS. Wire straighteners are made in the "double-roll" and the "rotary" types. The double-roll type is made in two forms — with rolls grooved to fit round wire and with wider plain rolls adapted to flat wire or ribbon stock. The double-roll and the rotary type of straightener are each adapted to its particular work and either may be applied, according to the characteristics of the article to be made or the quality of wire to be used.

The double-roll straightener is the one generally used. When used for round wire, one set of rolls is arranged horizontally and another set vertically, the rolls being grooved. For ribbon stock, the rolls are plain and arranged vertically only. The rolls are not located opposite each other but are staggered, and adjustment is provided for bringing them closer together or setting them further apart to accommodate various thicknesses of stock. The action is very much the same as when drawing a piece of wire through

the fingers. The wire is bent slightly in one direction and immediately afterwards in the opposite direction. If released, the wire would take an intermediate position about half-way between the two bends. The adjustment of the rolls is such that this bending back and forth takes out all bends and kinks and the wire leaves the straightener practically or "commercially" straight. A commercially straight wire appears absolutely straight to the average eye, and this is all that is required for most articles. There are articles, however, in which greater refinement is necessary as to straightness, and the double-roll straightener is displaced by the rotary type. The double-roll type is not adapted to the straightening of hard spring wire.

The rotary straightener has a steel spindle containing staggered steel guides. The wire is brought through a quill in the end of the spindle, and it then passes over the steel guides and out through the opposite end. The spindle is made to revolve rapidly and at the same time is reciprocated backward and forward, being mounted in a bracket on a slide and moving with the feed mechanism of the machine. With this type of straightener, wire can be made as nearly straight as it is possible to obtain it. For products such as typewriter bars, where perfect alignment must be had, the rotary straightener must be used to obtain satisfactory results. It is also used for working hard spring wire.

WIRING DIES. See Curling and Wiring Dies.

WIRING FRAME. Sometimes it is necessary to mount a curling or wiring die in a horizontal slide attached to the press bed so that it can be drawn out from under the die for the insertion or removal of work. These slides, called *wiring frames*, are operated by hand and are necessary on some presses; otherwise the work could not be inserted or removed from the die when the latter is directly beneath the punch, owing to the limited space. One design of special *wiring press* has a die slide which is automatically operated, thus avoiding hand operation and the resulting fatigue and loss of time.

WOOD BORING, AUGER SPEEDS. See Auger Speeds.

WOOD CREOSOTING. See Creosoting Process.

WOOD, FACTOR OF SAFETY. The belief that a timber with a so-called "factor of safety" of 3 or 4 will carry three or four times the load for which it is designed is erroneous and has been the cause of failures through the overloading of structures. Only a small part of the usual "factor of safety" for wood is available for taking care of overloading; most of it is required to allow for the known variations in the strength of clear wood, the effect of defects, the moisture conditions of service, and the duration of the load.

Some of the working stresses assigned by the Forest Products Laboratory,

Madison, Wis., to structural timbers, when compared with laboratory test data on small, clear specimens, have an apparent " factor of safety " as high as 10, but in reality such factors make allowance for an accidental overload of only 50 per cent. The " factor of safety " for timber is not designed to take care of large overloads. In good construction, occasional timbers might be expected to fail immediately if they were subjected to only twice their design loads. Forty per cent of the timbers would probably fail if such loads were applied for a long time.

WOOD LIFE. The life of wooden poles for transmission lines varies according to the kind of wood, rapidity of growth, amount of sap at time of cutting, and seasoning after cutting. The following figures, based on a large number of observations, indicate the average life of untreated poles: Cedar, 13 to 14 years; chestnut, 11 to 12 years; cypress, 9 to 10 years; juniper, 8 to 9 years; pine, 6 to 7 years. Poles cut during the winter months when the sap is low always have a longer life than those cut in summer when the sap is up. The proper seasoning of poles also has a great influence on their life. They should be trimmed and peeled immediately after being cut, and should be supported on skids in separate layers for a period of from six months to a year, so that they will be thoroughly air-dried. It is now almost universal practice to give the butts of the poles and sometimes the cross-arms and tops a preservative treatment. Often the entire pole is treated. There are a number of different preservative materials that may be used. The principal of these is dead oil of coal tar or so-called " coal-tar creosote." This is a distillate obtained from coal tar at temperatures ranging from 400 to 750 degrees F. Coal tar itself is a distillate by-product obtained in the manufacture of coal gas and coke at temperatures of from 1500 to 3000 degrees F. Coal tar is of little use as a wood preservative, but the creosotes are of great value.

WOOD, LIGHTEST. Balsa, one of the commonest trees in the forests of Costa Rica, is said to be the lightest of all known woods, weighing but 7.3 pounds per cubic foot. Ordinary cork is three times as heavy as Balsa wood. This wood is very soft, and can be readily indented with the finger nail. It absorbs water readily, but it may be treated with paraffin, and then used in making floats for life preservers and in the construction of life rafts. It is also used for buoys and floating attachments to light signals.

WOOD MOISTURE-RESISTANT COATINGS. Shrinking and swelling and internal stresses that cause warping and checking are brought about in wood by changes in the moisture content. Such changes are occurring continually when wood is exposed to changing atmospheric conditions, and the only way to prevent or retard them is to protect the wood from the air with

some moisture-resistant finish or coating. Linseed oil, although it is probably recommended more frequently than most of the other materials for moisture-proofing wood, was found in absorption tests by the U. S. Forest Service to be quite ineffective. Five coats of hot oil followed by two coats of floor wax failed to give any great protection. Oil paints form a film over wood, which is very durable even in exterior locations. Laboratory tests show, however, that such a film, although it may be continuous, does not prevent moisture changes in the wood. Graphite paints and spar varnish are about as effective as the ordinary oil paints with the heavier pigments.

Among the best coverings were found to be aluminum-leaf coating developed at the Forest Products Laboratory, Madison, Wis., particularly for the protection of airplane propellers. Such a coating can best be applied to large unbroken surfaces. Some asphalt and pitch paints also have high moisture-resisting properties.

WOOD, NAIL-HOLDING QUALITY. See Nail-holding Qualities of Woods.

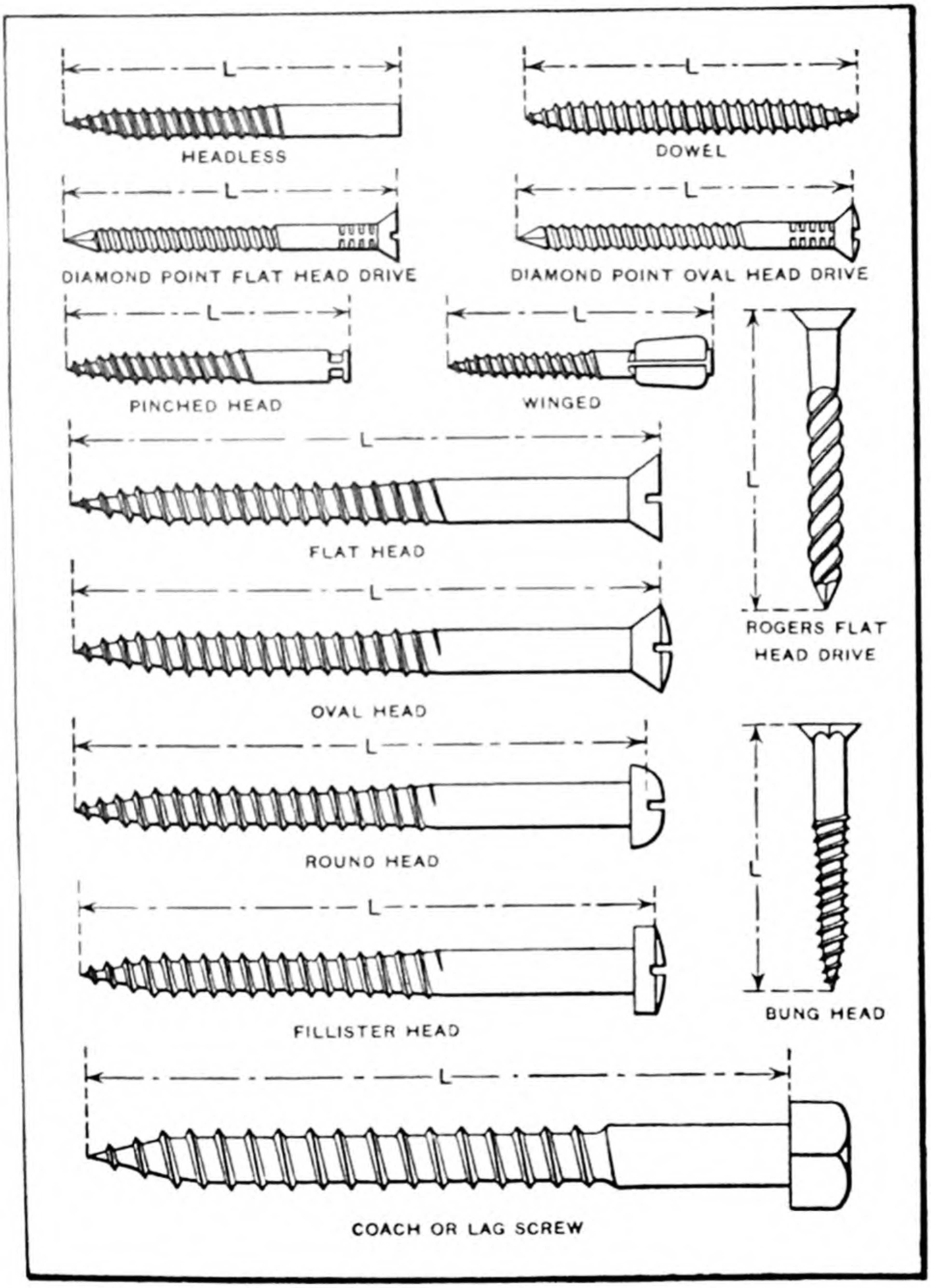
WOOD, PLASTIC. See Plastic Wood.

WOOD PRESERVING PROCESS. See Creosoting Processes; also Kyanizing.

WOODRUFF KEYS. In the Woodruff key system, half-circular disks of steel are used as keys, the half-circular side of the key being inserted into the keyseat. Part of the key projects and enters into a keyway in the part to be keyed to the shaft in the ordinary way. The advantage of this method of keys is that the keyway is easily milled by simply sinking a milling cutter, of the same diameter as the diameter of the stock from which the keys are made, into the shaft. The keys are also very cheaply made, as they are simply cut off from round bar stock and milled apart in the center. Dimensions of Woodruff keys are given in engineering handbooks.

WOOD-SCREWS. Various forms of wood-screws are shown in the accompanying illustration. The nominal length of the different forms is indicated by the dimensions L. With the round-head type, the length, instead of being from the under side of the head, includes about one-half of the head. The sizes of ordinary flat-head wood-screws, according to Asa S. Cook Co.'s standard, range from Nos. 0 to 30, No. 0 having a body diameter of 0.0578 inch, and No. 30, a diameter of 0.4546 inch. The minimum size has 30 threads per inch and the maximum, 6 threads per inch, the length of the thread being equal to two-thirds the length of the screw. A coach or lag screw has a square head instead of a slot, so that it can be turned by a wrench. These screws are often used in machine shops and

other manufacturing plants for fastening shaft hangers to wooden posts or floor beams, or for holding tools, in a fixed position on a wooden floor.



Wood-screws of Different Forms

WOOD-SCREW HOLDING POWER. One-half inch diameter wood-screws, driven 4 inches into wood, have a holding power of about 2500 pounds; ½-inch lag screws, driven 1½ inch into wood, have a holding power of about 1500 pounds, and, if driven 2½ inches into wood, of 2000 pounds. In all these tests the wood was Norway pine. Five-eighth-inch lag screws, driven

$4\frac{1}{2}$ inches into seasoned white oak, show a maximum holding power of 8000 pounds; the same screws driven into yellow pine, 4000 pounds.

WOOD SEASONING PROCESSES. There have been differences of opinion as to whether kiln-dried wood is as strong as wood that has been air-dried. In order to determine the relative properties, the Forest Products Laboratory of the United States Forest Service at Madison, Wis., made some 150,000 comparative strength tests on specimens from twenty-eight different common species of wood. The results of these experiments showed conclusively that good kiln-drying and good air-drying have the same effect upon the strength of wood. The belief that kiln-drying produces stronger wood than air-drying is usually the result of failure to consider differences in moisture content. The moisture content of wood, on leaving the kiln, is usually from 2 to 6 per cent lower than that of thoroughly air-dried stock. Since wood increases in strength with loss of moisture, higher strength values may be obtained from kiln-dried than from air-dried wood; but this difference in strength has no practical significance, since eventually a piece of wood will come to approximately the same moisture condition, whether it is kiln-dried or air-dried.

WOOD'S METAL. The composition of Wood's metal, which is a so-called "fusible metal," is as follows: 50 parts of bismuth, 25 parts of lead, 12.5 parts of tin and 12.5 parts of cadmium. The melting point of this alloy is from 66 to 71 degrees centigrade (151 to 160 degrees F. approximately).

WOOD, WEIGHT PER CUBIC FOOT. The following weights, in pounds, of various woods grown in the United States, are at the moisture condition of the trees when felled, if the wood is classified as "green." The air-dry weights are for wood at a moisture content of 12 per cent, which is approximately the condition reached without artificial heating by material sheltered from precipitation. In any lot of lumber of a given species in the air-dry condition at 12 per cent moisture, the weight per cubic foot will rarely vary more than 10 per cent from the figures given. In green material, on the other hand, the variation may occasionally be as great as 20 per cent, owing to wide differences in moisture content.

The figures following the name of each wood represent the weight per cubic foot, first, of green wood and then, of air-dry wood having a 12 per cent moisture content. Black ash, green, 52 — air-dry, 34; green ash, 49 — 40; white ash, 48 — 41; aspen, 42 — 27; basswood, 41 — 26; beech, 55 — 44; gray birch, 46 — 35; yellow birch, 58 — 43; Alaska cedar, 35 — 29; western red cedar, 27 — 23; northern white cedar, 28 — 22; southern white cedar, 26 — 23; black cherry, 46 — 35; chestnut, 55 — 30; southern

cypress, 51 — 32; American elm, 54 — 35; balsam fir, 45 — 26; Douglas fir, 38 — 34; black gum, 45 — 35; red gum, 50 — 34; eastern hemlock, 49 — 28; western hemlock, 42 — 28; pignut hickory, 64 — 53; shagbark hickory, 64 — 51; western larch, 48 — 36; bigleaf maple, 47 — 34; sugar maple, 56 — 44; black oak, 63 — 43; live oak, 76 — 62; white oak, 62 — 48; jack pine, 50 — 30; longleaf pine, 51 — 41; shortleaf pine, 51 — 38; western white pine, 35 — 27; western yellow pine, 45 — 28; balsam poplar, 42 — 22; yellow poplar, 38 — 28; redwood, 54 — 30; black spruce, 32 — 28; red spruce, 34 — 28; white spruce, 34 — 27; sycamore, 52 — 35; tamarack, 47 — 37; black walnut, 58 — 39; black willow, 50 — 26; Pacific yew, 54 — 44.

A practical rule for estimating the weight of air-dry or kiln-dry wood at a moisture content of about 12 per cent, is to regard a ½ per cent change in weight as accompanying a 1 per cent change in moisture content. For example, wood at 8 per cent moisture would weigh about 2 per cent less than at 12 per cent, while at 14 per cent the weight would be about 1 per cent more than at 12 per cent.

WORK. Work, in mechanics, is the effect of a force acting through a given distance, the force being usually measured in pounds or tons, and the distance in linear units, such as inches, feet, etc. Work is expressed as a product of the units of force (weight) and distance, and is given as inch-pounds, foot-pounds, foot-tons, etc. For example, in lifting a weight of 500 pounds to a height of two feet, 1000 foot-pounds of work has been performed. If one pound is lifted 1000 feet, or 1000 pounds, one foot, the same amount of work has been performed.

WORK-BENCH HEIGHT. See Benches.

WORKING GAGE. "Working gages" are those which are used in testing the work for size during the actual manufacture of the part. This type of gage has a greater amount allowed for wear than any other type, and hence the actual tolerance on the work between the maximum and minimum gage is smaller, by the amount allowed for wear on the gage, than the actual amount specified on the drawing. See Gage Classification.

WORKING LOAD. See Stress Definitions.

WORKING POINTS. The working or register points are those surfaces that are employed for locating parts in the jigs and fixtures during the process of manufacture. Sometimes important functional surfaces are used for this purpose. In other cases, for parts of irregular form, special lugs are provided and are removed after the machining operations are complete. As few locating points as possible should be established because this practice simplifies the design of the gages and other equipment.

WORM CONVEYOR. Same as Screw Conveyor.

WORM-GEAR APPLICATIONS. Worm gearing is employed for transmitting motion between two shafts which are at right angles to each other but which are not in the same plane. Strictly speaking, worm gearing is, therefore, a modified form of spiral or helical gearing, in which one gear takes the form of a screw or worm provided with threads, and the other of a gear with teeth inclined at the same angle as the threads in the worm. Worm gearing is generally used where high ratios are required. Worm gearing may be employed to transmit power where it is desired to obtain smoothness of action, and the reduction in velocity which such gears give. Worm gearing is also used where a great increase in the effective power is required; in this case, advantage is generally taken of the possibility of making the gearing self-locking. Such service is usually intermittent or occasional, and the matter of waste of power is not of so great an importance as in the first case. Examples of this application are to be found in the adjustments of a great many machine tools, in training and elevating gearing for ordnance, etc. The best material for worm gearing is hard phosphor-bronze for the worm-wheel and hardened steel for the worm. The next best materials are cast iron for the worm-wheel and hardened steel or cast iron for the worm. Steel or steel castings for both the worm-wheel and worm are only allowable for slow speeds. The teeth in the worm-wheel and the thread on the worm should always be cut, whenever the gearing is to be used steadily or at a reasonably high speed.

WORM-GEAR BRONZE. See Gear Castings, Bronze.

WORM-GEAR CUTTING. The machines used for cutting worm-gears include ordinary milling machines, gear-hobbing machines of the type adapted to cutting either spur, spiral, or worm gearing, and special machines designed expressly for cutting worm-gears. The general methods employed are (1) cutting by using a straight hob and a radial feeding movement between hob and gear blank; (2) cutting by feeding a fly cutter tangentially with relation to the worm gear blank; and (3) cutting by feeding a tapering hob tangentially. The fly-cutter method is slow as compared with hobbing but it has two decided advantages: First, a very simple and inexpensive cutter may be used instead of an expensive hob. This is of great importance when the number of worm-gears is not large enough to warrant making a hob. Second, with the fly-cutter method, it is possible to produce worm-gears having more accurate teeth than are obtainable by the use of a straight hob. Taper hobs are especially adapted for cutting worm-gears that are to mesh with worms having large helix angles; they are also preferable for worm-gears having large face widths in proportion to the worm diameter.

Worm-gear teeth are generated more accurately with a taper hob than with a straight hob that is given a radial feeding movement.

WORM GEARING, HINDLEY. See Hindley Worm Gearing.

WORM-GEAR POWER-TRANSMITTING CAPACITY. In determining the allowable load for worm gearing, the danger of overheating and of abrasion are usually of greater importance than the strength, because if the gearing is so proportioned as to prevent abrasion and overheating, the strength will ordinarily be greater than is required merely to withstand the stresses due to the load. Overheating is the cause of most worm-gear failures. It indicates that the frictional loss is so great that the heat is generated faster than it can be dissipated; consequently the action of the lubricant becomes less effective as the temperature rises, which, in turn, causes a further increase in frictional resistance. Finally, the oil film between the surfaces and contact is no longer maintained and abrasion begins. It is evident that there is less danger of overheating and abrasion with lower velocities and intermittent service, and also when a lubricant of good quality is used.

In designing worm drives, the worm diameter should be as small as possible to reduce the velocity. If the worm diameter is unnecessarily large, the gearing may become hot and start to cut. Another important point is to use a multiple-threaded worm in preference to a single-threaded worm whenever conditions permit, to increase efficiency. For determining the power that worm gearing will transmit without danger of excessive heating or abrasion, the Lewis formula for spur gears may be used, the calculations being based on the velocity of the worm-gear; that is, insert in the formula for spur gears the velocity of the worm-gear in feet per minute, its diametral pitch, and face width as measured along the pitch circle of the worm.

WORM GEAR STANDARDS, A. G. M. A. The American Gear Manufacturers' Association adopted in October, 1923, and revised in May, 1927, recommended practice covering formulas and specifications for the design of standard worm gearing. This practice applies to worm gearing in the general industrial range which includes linear pitches from $\frac{1}{4}$ inch to 2 inches; single, double, triple and quadruple threads; and gear ratios from 10 to 1 to 100 to 1.

This group includes the worm gearing demanded by the trade for general commercial uses, where the gearing is furnished without bearings or housings and does not include the gearing of units, shaft worms, smaller or larger pitches than that mentioned, worms having more than four threads, gear ratios greater than or less than that specified, gearing with the axis other than 90 degrees or where the duty required or quantity involved justifies a

further refinement of design than that used in the case of these general purpose worms and gears.

Thread Form. — The thread form regarded as standard is the form produced by a straight-sided milling cutter having a diameter not less than the outside diameter of the worm nor greater than $1\frac{1}{4}$ times the outside diameter of the worm. The sides of the cutter are to incline $14\frac{1}{2}$ degrees in the case of single- and double-thread worms, and 20 degrees for triple- and quadruple-thread worms.

Linear Pitches. — The linear pitches, in inches, regarded as standard for the industrial range of gearing are $\frac{1}{4}$, $\frac{5}{16}$, $\frac{3}{8}$, $\frac{1}{2}$, $\frac{5}{8}$, $\frac{3}{4}$, 1, $1\frac{1}{4}$, $1\frac{1}{2}$, $1\frac{3}{4}$ and 2. This series of eleven pitches in conjunction with the use of single-, double-, triple- and quadruple-threads gives a total series of forty-four worms, which is considered a large enough selection to cover ordinary service requirements.

Single- and Double-thread Worm Formulas. — If LP = linear pitch and N = number of worm gear teeth, then pitch diameter $= 2.4 \times LP + 1.1$; outside diameter $= 3.036 \times LP + 1.1$; root diameter $= 1.664 \times LP + 1.1$; hub diameter $= 1.664 \times LP + 1$; bore diameter (maximum) $= LP + 0.625$; face length (length of threaded section) $= LP \times \left(4.5 + \frac{N}{50}\right)$; hub extensions $= LP$; hub length $= FL + 2 \times LP$; addendum $= 0.318 \times LP$; whole depth of tooth $= 0.686 \times LP$.

The lead angle is measured from a plane perpendicular to the axis of the worm. To find the cotangent of this angle multiply the pitch diameter by 3.1416 and divide the product by the lead. The normal tooth thickness $= 0.5 \times LP \times$ cosine lead angle. The outer corners of the worm thread are rounded at an amount equal to $0.05 \times LP$.

Triple- and Quadruple-thread Worm Formulas. — Outside diameter $= 2.972 \times LP + 1.1$; root diameter $= 1.726 \times LP + 1.1$; hub diameter $= 1.726 \times LP + 1$; addendum $= 0.286 \times LP$; whole depth of tooth $= 0.623 \times LP$. For other dimensions use the formulas given for single- and double-thread worms.

Worm-gear Formulas. — Worm gears for use with worms proportioned according to A. G. M. A. recommended practice should be designed according to the following formulas in which LP = linear pitch of worm or circular pitch of worm gear, N = number of gear teeth, PD = pitch diameter, TD = throat diameter, BD = bore diameter, FW = face width of gear.

Formulas for Gears Used with Single- or Double-thread Worms. — As single- and double-thread worms have an angle of obliquity of $14\frac{1}{2}$ degrees, whereas triple- and quadruple-thread worms have an angle of 20 degrees, some of the formulas for gears used with single- and double-thread worms differ from those used with triple and quadruple. For single and double threads: Pitch diameter $= N \times 0.3183 \times LP$; throat diameter $= PD$

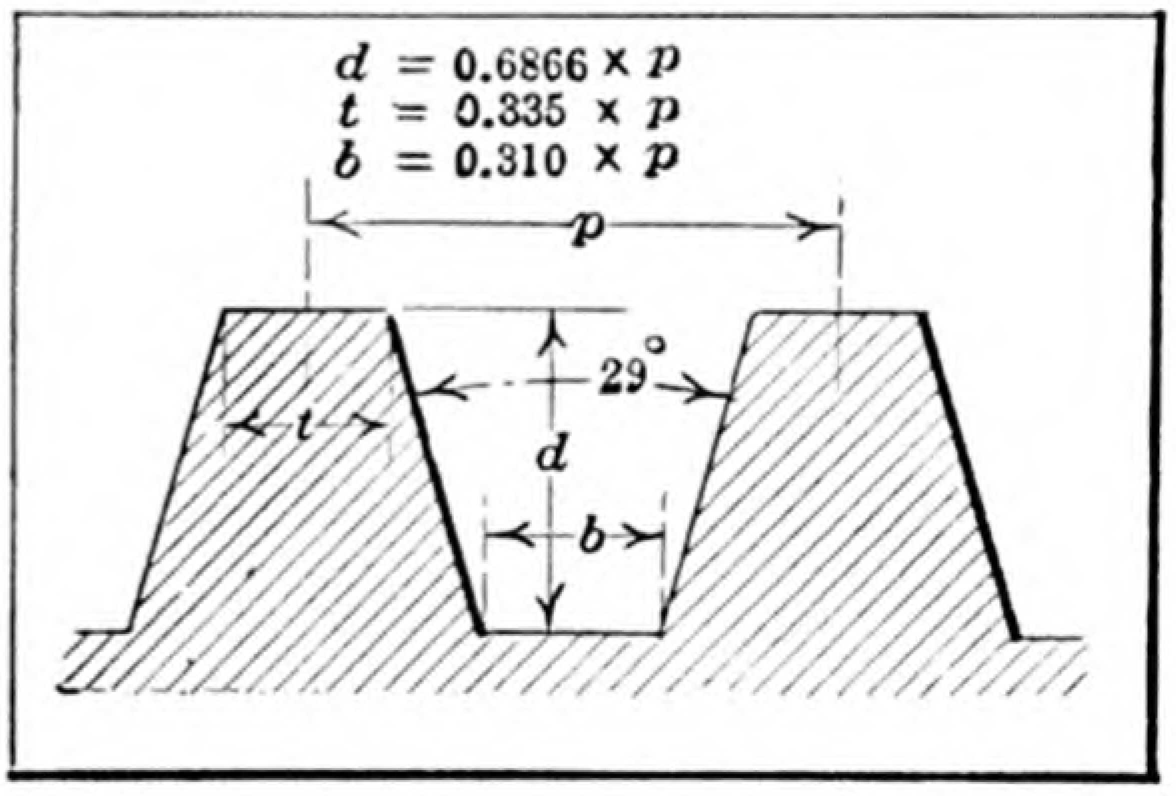
+ $(0.636 \times LP)$; outside diameter = $TD + (0.4775 \times LP)$; hub diameter = $1.875 \times BD$; face width = $2.38 \times LP + 0.25$; hub extensions = $0.25 \times BD$; hub length = $FW + 0.5 \times BD$; radius of wheel face (throat radius) = $0.882 \times LP + 0.55$. The outer edge or corner of the gear rim is rounded an amount equal to $0.25 \times LP$.

Formulas for Gears Used with Triple- and Quadruple-thread Worms. — The following formulas for gears used with triple- and quadruple-thread worms differ from those for single- and double-threads owing to the 20-degree angle of obliquity for triple and quadruple threads.

Throat diameter = $PD + (0.572 \times LP)$; outside diameter = $TD + (0.3183 \times LP)$; face width = $2.15 \times LP + 0.2$; radius of wheel face (throat radius) = $0.914 \times LP + 0.55$. Formulas for other dimensions are the same as previously given for gears used with single- and double-thread worms.

Worm-gear Hobs. — It is recommended that single- and double-thread hobs be fluted parallel to the axis, and triple- and quadruple-thread hobs be fluted normal to the thread or helix angle as determined from the outside diameter of the hob.

WORM THREAD. The worm thread ordinarily used in general machinery construction has straight sides in the plane of the axis and an included angle of 29 degrees (see illustration). This angle is the same as that of the Acme thread, but the worm thread depth is greater and the widths of the flats at the top and bottom are less. If the lead angle or angle between the worm thread helix at the pitch cylinder and a plane perpendicular to the worm axis, is comparatively large, difficulties may be encountered if a 29-degree worm thread is employed, and many worms (in automobile transmissions especially) have an included thread angle of 60 degrees. If the lead angle is larger than about 20 degrees, an increase in the included thread angle is desirable. As the efficiency of worm gearing reaches a maximum when the lead angle is about 45 degrees, this explains why 60-degree thread angles have been applied in many automotive drives. The formulas for the thread parts of a 29-degree worm thread are as follows:



Worm Thread

$$p = \text{pitch} = \frac{1}{\text{No. of threads per inch}};$$

$$d = \text{depth of thread} = 0.6866\,p = \frac{0.6866}{\text{No. of threads per inch}};$$

$$t = \text{width at top of thread} = 0.335\,p;$$

$$b = \text{width at bottom of thread} = 0.310\,p.$$

WORM THREAD CUTTING. Worm threads are cut either by using some form of thread-cutting lathe and a single-point tool, by using a thread milling machine and a disk type of cutter, or by using a gear-hobbing machine. Worm threads for general machinery construction should preferably be cut so that the sectional shape of the thread in an axial plane conforms to the shape of a standard involute rack, the included angle of the thread being 29 degrees, and the total depth of the thread groove being equal to 0.6866 × pitch of worm. This rack shape may be obtained by using a properly ground lathe tool set so that the plane of the cutting edges coincides with the axis of the worm; if the tool is set normal or at right angles to the sides of the worm thread, the sectional shape of the thread in an axial plane will be modified.

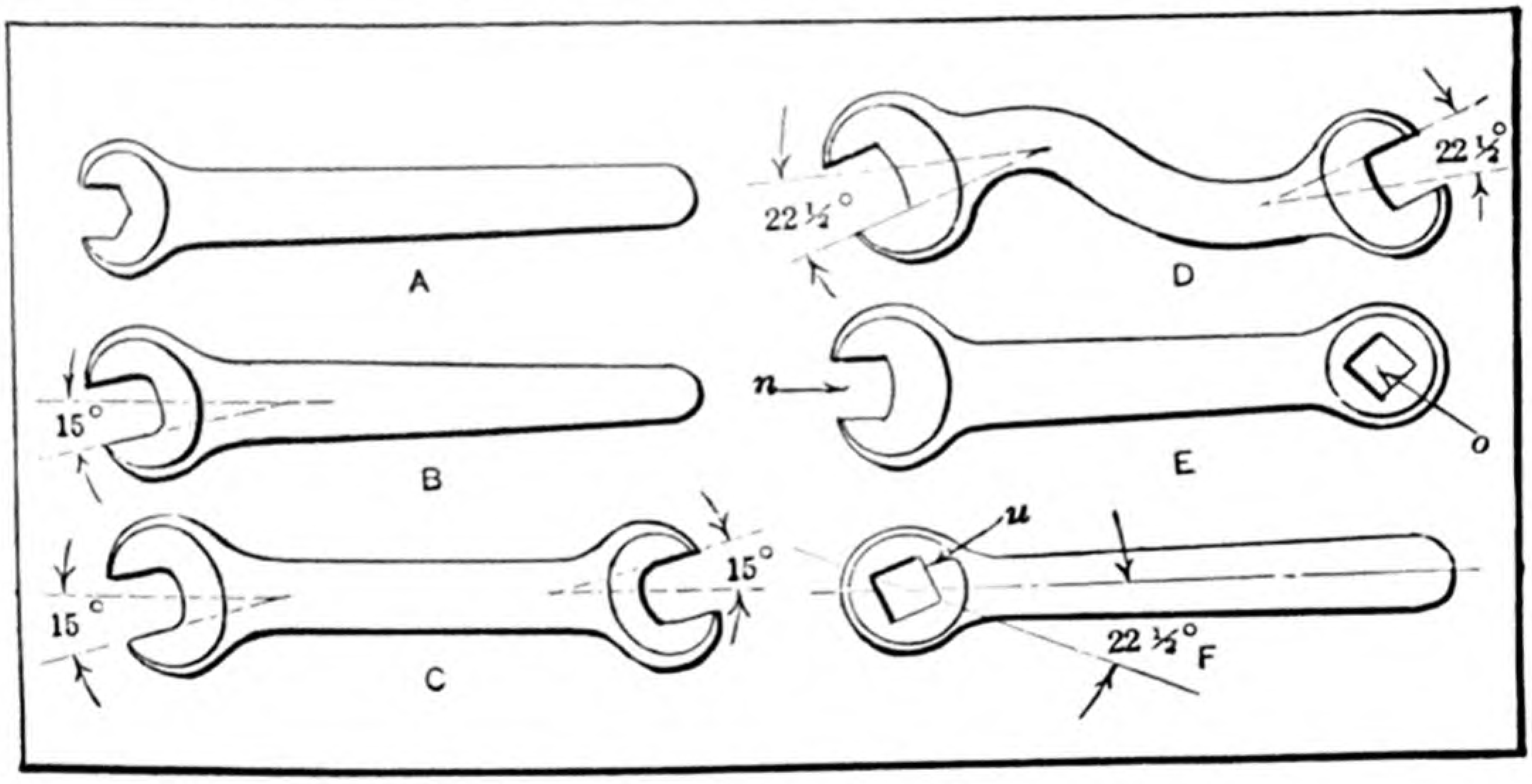
Worm Hobbing. — The hobbing method, with its inherent advantage of progressive and continuous indexing and high production, has been applied successfully to the hobbing of worms. One of the features of this method is the special form of helicoidal cutter or hob employed. The design of this hob permits worms to be hobbed which have a shoulder on either or both ends. The teeth are arranged helically as in regular gear hobs. There are about fourteen roughing and three finishing teeth or about one and one-half or two convolutions of teeth, thus making the hob much shorter than gear hobs, the length being about twice the normal linear pitch of the worm to be cut. The action of the hob is in the nature of a progressive roughing and finishing cut.

WORM THREAD GRINDER. Hardened or unhardened worms may be finished by grinding the threads in a machine so arranged that the worm is rotated and traversed relative to the grinding wheel, which is inclined to suit both helix angle and thread or pressure angle. One commercial design of worm thread grinding machine grinds one side of the thread at a time, the worm being turned end for end to grind the opposite side. The grinding wheel operates while the table is traveling in one direction, and is withdrawn for the table return. Multiple-thread worms are indexed during the return stroke. The wheel-spindle is mounted on the upper of two slides, the lower one being automatically fed to and from the work by a hydraulic arrangement. A travel of $1\frac{1}{4}$ inches is provided, so that the wheel clears the work while the worm is indexing and the table returning to the cutting position. Provision is made to swivel the wheel-spindle through 180 degrees to permit grinding worms of either hand. A diamond that is adjustable to

the required pressure angle is used to keep the wheel shape correct. The wheel is moved in to the diamond, and is therefore always in proper position relative to the worm center line. The table travel is controlled by means of adjustable dogs. The depth of cut is controlled by moving the table endwise toward the grinding wheel, which may be done by hand or automatically after each complete revolution of the worm. Throw-out shoes on the feed ratchets permit a predetermined amount of stock to be ground off.

WORTLE STEEL. See Tungsten Steel.

WRENCHES. A group of wrenches commonly used in general mechanical work is shown by the engraving. The *straight single-end wrench* at *A* is designed for use on either hexagon or square nuts and bolts, on plain work where there are no interferences. This type of wrench is also made double, with a different size of opening at each end. The *single-end 15-degree angle*

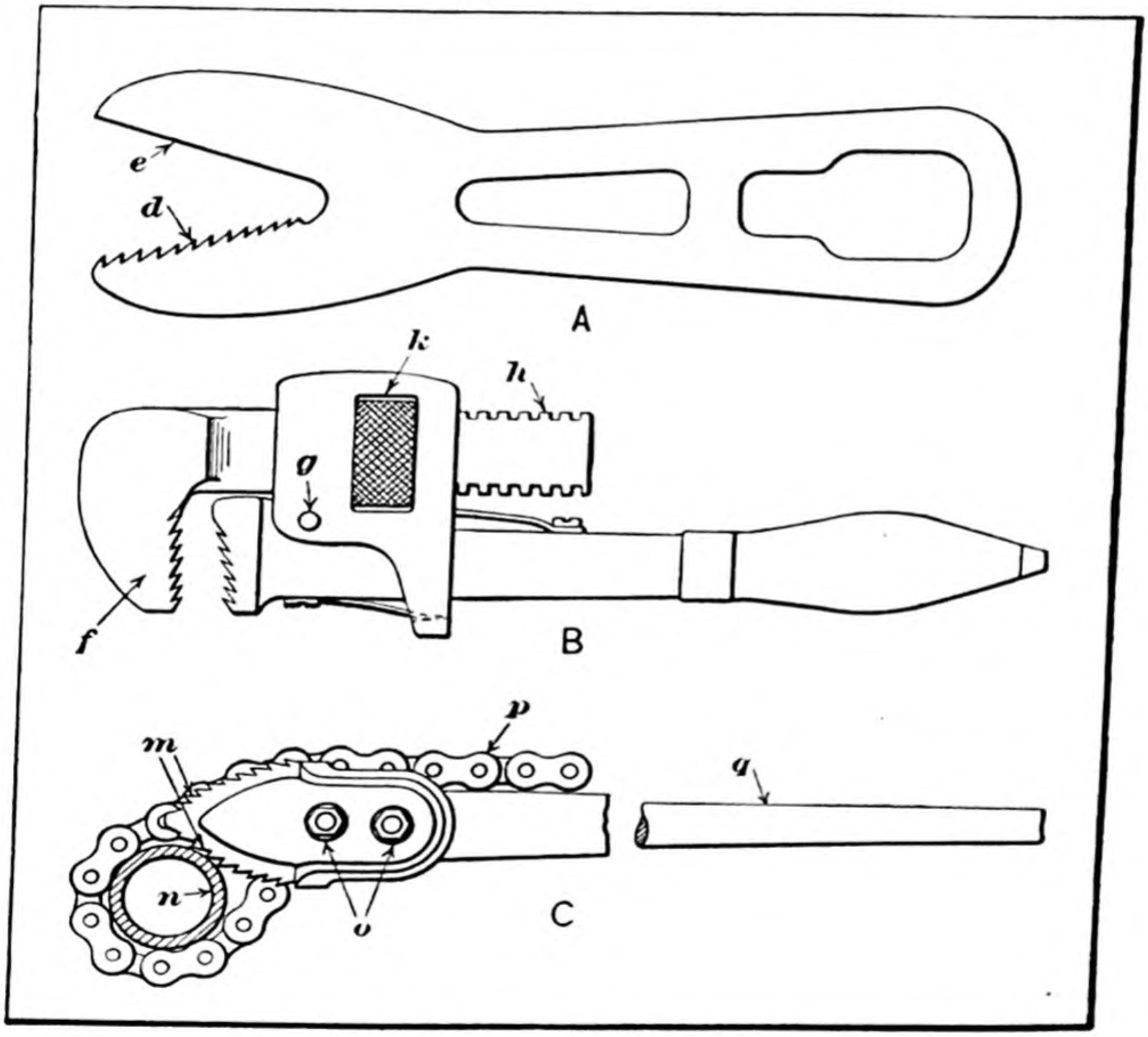


Non-adjustable Wrenches

wrench, shown at *B*, is a very common type of wrench, the offset of which is made in order to permit its use in more confined situations, where the handle might strike if it were made straight. The *double-end 15-degree angle wrench C* is of the same general type as *B*, the ends being offset and with different sizes of openings. The *double-end 22½-degree angle wrench D* is particularly useful in loom repairing and for textile workers. It is intended especially for square-head nuts and bolts on account of the greater swing of wrench needed in setting up. The *double-head toolpost wrench E* is made with one end *o* broached square, so that it is not likely to slip off the post when in use. The other end *n* is usually made to take some standard size of nut used on the machine. The *square-box 22½-degree angle toolpost wrench F* is also broached and is designed primarily for a lathe toolpost. The angle of the broached hole *u*, in relation to the handle, is such as to give

greater latitude when the operator's hand is likely to come in contact with the work, or portions of the machine. The offsets commonly used for non-adjustable wrenches are 15 degrees for a hexagon and $22\frac{1}{2}$ degrees for a square-head bolt or nut, these angularities being, in each case, one-quarter of the angle of the arc subtended by one side of the nut. When nuts are located in such a way that there is not sufficient room to swing a straight wrench through the necessary angle, the offset type can be used to advantage. See Socket Wrenches; Spanner Wrenches.

WRENCHES FOR CYLINDRICAL WORK. The *alligator wrench* at *A* indicates clearly the origin of its name. One of the jaws *d* is provided with a set of teeth, while the other, *e*, is smooth. When in use, the teeth "bite"



Alligator and Pipe Wrenches

into the pipe or other cylindrical work, and a wedging action takes place as the pipe works farther up into the jaws, so that it becomes tighter as pressure is applied. The *Stillson* type of wrench, *B*, is commonly used for pipe work of all kinds. The jaw *f* is L-shaped, flattened on the sides, and has a thread of coarse pitch at *h*. The jaw is mounted in a holder pivoted at *g* to the solid portion of the wrench, the adjustment being obtained through the knurled

nut *k*. When pressure is applied, the pivoted portion in connection with the fixed jaw tends to grip the work more and more tightly, according to the amount of force used in the application. The *chain-type of wrench, C*, is commonly used on work requiring considerable leverage, such as heavy steam fitting and street pipe work. The handle *q* is often made in lengths of from 2 to 6 feet. There are two jaws *m*, one of which is fastened to each side of the bar by the nuts and bolts at *o*, these jaws being provided with teeth which " bite " into any cylindrical object on which they are used, as shown at *n* in the illustration. The chain portion *p* may be drawn around the pipe to an approximation of the correct diameter, after which provision is made between the jaws for tightening the chain. This is done either by means of protruding lugs, or by an extension of the rivet ends through the chain blocks in such a way that they will drop into slots in the jaws.

WRINGING FIT. This is a fit between two parts, one cylindrical and the other with a cylindrical bore, of such a character that one part cannot be pushed easily into the other, but can be made to enter by a twisting motion, the parts being turned or twisted as they are forced or " wrung " together by hand.

WROUGHT ALUMINUM BRONZE. See Aluminum Bronze, Wrought.

WROUGHT IRON. Wrought iron is a slag-bearing malleable iron which contains comparatively little carbon (0.3 per cent or less). It is more easily forged than steel and can be welded readily; it cannot be hardened or heat-treated the same as steel, but can be casehardened by the use of cyanide of potassium. It has a high electrical conductivity and magnetizes easily. Wrought iron should never be used for bearing surfaces, as its slag content causes heating and wear, but it is suitable for parts such as chain links, rods, angles, braces, levers, etc., and for use when subjected to high temperatures.

Grades of Wrought Iron. — Wrought iron is graded in many ways, there being no standard system. It is sometimes divided simply into two classes — *charcoal iron*, which is made from charcoal pig and is usually refined and double refined, and *common iron*, which is made from coke pig. According to another system, it is graded in three classes as *charcoal iron; puddle iron*, which is divided into Classes A, B, and C, or into staybolt iron and merchant iron; and *busheled scrap iron*, which is made from iron scrap which frequently contains pieces of steel. According to still another classification, it is graded as *Norway* or, more correctly, *Swedish iron*, which is very fibrous and used for the best class of work; *double-refined* or *best-refined iron*, which is the best domestic iron, and is used for forging, welding, and machine work; *refined iron*, which is a good grade of wrought iron; and *common iron*, which is made either from pig iron or from scrap, and which does not weld as readily as the other grades.

Wrought iron has, to a large extent, been superseded by mild steel. Nevertheless, its resistance to fatigue and the ease with which it can be welded render it valuable for many purposes. Although it is frequently referred to as "Norway" iron, probably the best wrought iron made comes from Sweden. This iron is unusually free from sulphur and phosphorus — ingredients which have an injurious effect upon the metal.

Strength of Wrought Iron. — Wrought iron is ductile and malleable. Its strength and physical properties depend upon various conditions, but the ultimate strength in tension is about 48,000 to 50,000 pounds per square inch. If wrought iron is assumed to have a strength of 100 per cent at 70 degrees F., its strength at 400 degrees F. is about 112 per cent and at 570 degrees F., 116 per cent, after which there is a falling off, so that the strength at 750 degrees F. is 96 per cent, and at 1100 degrees F., 42 per cent.

Refined and Double-refined Wrought Iron. — Refined wrought iron is made by melting pig iron and puddling it in a puddle furnace in the same way as common iron. The bars, however, are subjected to a second heating and re-rolling thus producing what is known as "refined" iron. *Double-refined* iron is also made from pig iron, and passes through the same process in the puddling furnace, and is rolled through the puddle rolls, cut up, heated, and re-rolled the same as refined iron, but the bars thus obtained are again cut up, made into box piles, reheated, and again run through the rolls. The double rolling of the metal makes it very fibrous. Double-refined wrought iron is a very good material having an ultimate tensile strength of about 50,000 pounds per square inch with an elongation of 28 per cent. It is used extensively in the construction of passenger and freight cars, because of its ductility and its quality of being able to withstand shocks and constant vibration better than steel.

WROUGHT IRON MANUFACTURING METHODS. In the ordinary manufacture of wrought iron, pig iron is melted in a puddling furnace where most of the silicon, carbon, phosphorus, and other impurities are separated from the iron, forming the puddle cinder. About one-half ton is charged in the furnace at a time. The puddler endeavors to fuse the whole charge at as nearly one time and at as low a temperature as possible. This is accomplished by moving the pigs about with a paddle or "rabble," thereby exposing fresh surfaces to the flame and to the dissolving influence of the cinder bath. The cinder produced during the welding oxidizes and absorbs a large portion of the silicon and manganese. As the temperature increases, rapid decarbonization takes place, giving off a large volume of carbon monoxide which causes the bath to swell or "high boil." Vigorous agitation of the bath is vitally important throughout the process, to produce uniform conditions in all parts, and to prevent any portion continuing to rest upon the relatively cool bottom.

Pig iron melts at about 2100 degrees F., steel at about 2500 degrees F., and wrought iron at about 2800 degrees F. The temperature in the puddling furnace is high enough to melt pig iron, but not high enough to keep wrought iron in a liquid state; therefore, as soon as the small particles of iron become purified, they partly congeal (" come to nature "), forming a spongy mass in which small globules of iron are in a semi-plastic state. This mass is divided by the puddler into " puddle balls " or lumps of about 200 pounds each. These lumps are formed into elongated blooms in a rotary squeezer or under a steam hammer, and, while still hot, rolled out between the puddle rolls into bars of from 3 to 6 inches wide, $\frac{3}{4}$ inch thick, and from 15 to 30 feet long. These bars are called " puddle-bars " or " muck-bars," and, owing to the large amount of cinder still contained, they have rather rough surfaces. The muck-bars are cut up into pieces of from 2 to 4 feet long, and piled on top of each other in " piles " varying in weight from 100 to 2000 pounds. These piles are heated in a reheating furnace, and when white hot are taken to the rolls to be rolled out and welded together into iron bars, sheets, plates, or structural shapes. Instead of starting the process with pig iron, as described, scrap iron can also be employed.

The ordinary double puddling furnace is of simple construction, consisting of a fire chamber, a working hearth, and a flue. The bottom of the hearth is composed of pure oxide of iron resting upon a cast-iron air-cooled bottom. The sides of the hearth are formed of iron ore, technically known as " fix " or " fettling."

Mechanical Puddling. — To puddle iron successfully by mechanical means, it is necessary to approach as nearly as possible the conditions in the hand furnace — in other words, it means being able to mix iron and cinder intimately, to expose every part of the sponge to the heat, and to have full control of cinder and flame conditions. In an effort to accomplish this, one type of Furnace (the Roe furnace) is so arranged that it can oscillate through an angle up to 120 degrees. The furnace is operated in the following manner: The working bottom, which is formed of pure oxide of iron, is obtained from a small tilting open-hearth furnace in which the oxide is melted. It is then poured into a cast-iron ladle and charged into the puddling machine through a hole in the side near the rail. It flows uniformly over the bottom where it rapidly congeals, as its temperature of fusion is high. Following this, the puddling cinder melted in the same type of furnace is charged in the same manner and flowed over the bottom and over the door joint, where it congeals and forms a liquid-tight joint. Immediately after this, molten iron from a mixer is charged. Next, the oxidizing agent — roll scale — is charged by means of a long spoon, which distributes the scale uniformly through the whole width of the furnace.

Between spoonfuls the machine oscillates rapidly about 45 degrees each

side of the horizontal. During this period air and gas are shut off, producing an oxidizing atmosphere in the furnace, and all the silicon and manganese is oxidized. Gas and air are then admitted, and as the temperature increases, the reactions become apparent and increase in intensity until the high boil is attained, which is the period of the most rapid decarburization; during the whole of this period the machine is moved rapidly, producing violent agitation of the whole bath, with intermissions between each successive five or seven oscillations. As evidence of the " drop " appears, that is, when most of the carbon has been eliminated, the motion is changed to an extremely slow one, and at a somewhat smaller angle, the object now being to prevent the plastic and partially refined mass from going together, as, should it do so, the center of the mass would not be completely refined. Keeping the iron sponge open at this period is a vital feature, and one that the particular form of bottom used is intended to attain. The whole period of making a heat averages 60 minutes.

Rotating and Oscillating Furnace. — Another process for making wrought iron utilizes a furnace which is so arranged that it can be both rotated and oscillated. Fuel oil is used as a fuel, although pulverized coal has been successfully tried out and ordinary coal can be used in certain ways. In the course of the operation, the furnace lining is first heated to a temperature of 2400 degrees F., after which a quantity of iron turnings and ferric oxide is introduced in small pieces into the furnace chamber. The furnace is then rotated until the " fix " softens and finally flows freely, ultimately adhering in a solid coating to the magnesite lining of the furnace. A mixture of brown and red hematite ore is used to seal the edges of the lining around the ports where they are exposed. This is claimed to produce a good wear-resisting bottom. After the lining of the furnace is prepared, a quantity of rolled scale and cinder is shoveled in, and after these are partially melted or fused, the furnace is rotated into the proper position and a charge of molten pig iron poured in. As soon as this is done, the door is closed and the furnace rotated enough to cause the slag, which now is fluid, to flow to the door sill and jambs and seal the furnace door tightly. The temperature of the furnace is maintained with a reduction in the air supply in order to bring on a boil. During this period, the furnace is oscillated through an arc of about 60 degrees, and rolled scale is added. As the boiling period recedes, the metal commences to " come to nature," with a lowering of the temperature of the charge, the furnace during this period being oscillated constantly in order to break up the slag film and expose the granules of the metal to the decarbonizing action of the slag and flame. When the metal has fully " come to nature," the furnace is rotated to form the mass into a ball, and at the same time the furnace temperature is maintained at a melting heat so that the particles of iron are homogeneously welded together and the slag

maintained fluid. It is very important that the slag be of such a character that, while viscous enough to stick to the iron, it will not be so basic as to require extremely high heating for subsequent welding operations.

Pouring Process. — The principle of another process is based on the production of an intimate mixture of molten iron and oxide of iron by making the charge pour repeatedly over a dam in a thin stream in an oscillating furnace. The melting stage is carried on in a cupola, from which the molten iron goes into the puddling furnace where the operations of purifying, boiling, and balling follow mechanically the hand method. Essentially, the furnace consists of a cylinder of steel plate about 6 feet in diameter and 5 feet 6 inches long, with projecting trunnions 18 inches in diameter. The cylinder is lined with magnesite brick to an inside diameter of about 4 feet. The dam, which consists also of magnesite brick, extends up nearly to the center line. The operation is carried on at a temperature of about 2650 degrees F., the flame temperature, using oil fuel, being 2850 degrees. As soon as the iron begins to form into a ball, the oscillating motion of the furnace is stopped and the furnace is rotated clear over. The ball is carried to a squeezer, where it goes down through a passage of continuously decreasing dimensions and thence it is expelled in rough cylindrical form at the far side, free from surface slag and prepared for the breaking-down rolls. The iron is used largely for pipe and sockets, engine bolts, staybolts, and high-grade merchant bars. Its physical properties vary in tensile strength from 45,000 to 52,000 pounds, and in elongation from 15 to 30 per cent.

Walloon Process. — The method of making wrought iron, known as the *Walloon process*, consists in the melting of long pigs by gradually pushing them forward into a charcoal fire. As the iron melts, it drops and collects in a pasty mass at the bottom of the furnace. In dropping, it passes through a blast of air and becomes partially decarburized and converted into wrought iron. This partially refined iron is then remelted in a charcoal fire, rich slag and hammer scale being added, after which the metal is formed into balls, reheated, and hammered or rolled. This process is used in Sweden for producing wrought iron from Dannemora pig iron.

WROUGHT PIPE DEFINED. The terms "wrought pipe" and "wrought-iron pipe," at one time were practically synonymous, for originally all pipe was made of wrought iron, but the use of steel pipe has increased so rapidly that now at least 90 per cent of the wrought pipe made in this country is of that material. "Wrought pipe" is a term that is applied to both steel and iron pipe. The term "wrought-iron pipe" means that the pipe is made of wrought iron, which is the product of the puddling furnace; while "steel pipe" is applied, of course, only to pipe made of steel.

WÜEST HERRINGBONE GEARS. See under Herringbone Gears.

X-RAYS. X-rays, also known from their discoverer as *Röntgen rays*, are generated when the cathode rays of a vacuum tube impinge upon any solid substance. All substances, many of which are opaque to ordinary light, transmit X-rays to some degree. A somewhat interesting relationship exists between the transparency of any substance and its specific gravity; the transparency to X-rays is approximately inversely proportional to the specific gravity of the substance. X-rays are of the same general character as light waves, but so short that they readily penetrate all sorts of materials usually opaque to visible light. They are produced commercially by a very high voltage discharge in a special type of vacuum tube, and their ability to penetrate materials increases with the voltage, but decreases as the atomic weight of the materials increases. Thus, X-rays produced at 100,000 volts may penetrate satisfactorily an inch of steel, several inches of aluminum or a foot or more of wood, whereas more than 200,000 volts would be required to produce X-rays to penetrate three inches of steel.

The usual way of recording X-rays is by the "shadow picture," or radiograph, formed on a photographic film. As with ordinary photographs, darker regions on the negative or lighter regions on the print mean that more light has passed through the object at that place — that is, the object is more transparent there.

Serious waste in the machine shop often occurs because of internal defects discovered in the work after considerable machining has been done. While these conditions are, perhaps, more prevalent in castings, they also occur in forgings and in bar or plate stock. Where it is a question of machining large and important castings, X-ray inspection may be of particular importance. Detailed pictures of all sorts of cast articles can be secured with comparative ease and speed, so long as the greatest thickness does not exceed $3\frac{1}{2}$ inches of steel or its equivalent.

Equipment which can be used in making X-ray pictures of castings etc., consists of a high-voltage power plant capable of producing 280,000 volts, an X-ray tube mounted in a lead-covered steel drum to prevent the escape of X-rays except through predetermined openings, and an exposure cabinet provided with movable lead screens to surround the object under examination.

XYLENE. Name applied to any of three isomeric hydrocarbons, $C_6H_4(CH_3)_2$, of the benzene series, found in coal and wood tar and certain kinds of petroleum, and also prepared artificially. They are dimethyl derivatives of benzene and are called specifically orthoxylene, metaxylene or isoxylene, and paraxylene. All are ordinarily colorless oily liquids, and each is the parent substance of a distinct series of compounds.

YARD. One yard equals 3 feet or 36 inches. Since 1893 the United States yard and its subdivisions have been derived from the international meter. The basic relation officially recognized is that contained in the law of July 28, 1866, and set forth in the Mendenhall order of April 5, 1893; namely,

$$\frac{1 \text{ yard}}{1 \text{ meter}} = \frac{3{,}600}{3{,}937}$$

Y-CONNECTIONS. In a three-phase, alternating-current system, the generators and motors are designed with three windings or phases, connected either in mesh or with delta connection, in which case the diagram of the three windings forms a Greek letter delta (Δ), or in star or Y-connection, when the diagram of the three windings forms a Y.

YELLOW METAL. This is a brass containing about 40 per cent of zinc and 60 per cent of copper. See Brass Alloys for Castings.

Y-FITTING OR WYE. A fitting either cast or wrought that has one side outlet at any angle other than 90 degrees. The angle is usually 45 degrees, unless another angle is specified. The fitting is usually indicated by the letter Y.

YIELD-POINT. When testing a bar of metal in a testing machine, a point will be arrived at where there will be an extension of the bar without an increase of the load. This point is called the *yield-point*. Practically, it may be considered as the point at which a certain load per square inch will cause a distinctly visible increase in the distance between the gage points on the test-piece; or it may be considered to be the point at which, when the load is increased at a moderately fast rate, there is a distinct drop of the testing machine lever, or, in hydraulic testing machines, of the gage finger. A steel test-piece at the yield-point shows rapidly a large increase of extension. The yield-point should not be confused with the elastic limit, which is the point at which extensions in a material under stress cease to be proportional to the loads.

Y-LEVEL. The Y-level, frequently also called "wye level," is an engineer's or surveyor's spirit level, the name being derived from the fact that the telescope rests in the Y's of the instrument. The Y-level has been, to a certain extent, superseded by the so-called "dumpy" level or Gravatt level.

YOUNG'S MODULUS. The modulus of elasticity of a material — that is, the quotient obtained by dividing the stress per square inch by the elongation in one inch caused by this stress — is often referred to as *Young's modulus*, from the name of the first investigator who pointed out this relationship.

ZEE SECTION. A standard structural shape consisting of a web and flanges extending at right angles to the web but in opposite directions. See Structural Shapes.

ZERENER ELECTRIC WELDING PROCESS. In the Zerener electric welding process (also known as the "electric blow-pipe" method), an electric arc is drawn between two carbon electrodes. This arc is then caused to impinge upon the metal surfaces to be welded by means of an electromagnet. The arc is pointed to concentrate the heat, and the metal is fused around its point of contact with the arc.

ZERO, ABSOLUTE. See Absolute Temperature.

ZINC. Zinc is a metallic chemical element. Its chemical symbol is Zn; atomic weight, 65.37; melting point, 786 degrees F. (419 degrees C.); boiling point, at atmospheric pressure, 1904 degrees F. (1040 degrees C.). The specific gravity of cast zinc is from 6.86 to 6.91; specific gravity of rolled zinc, from 7.15 to 7.19; coefficient of linear expansion per unit of length per degree F., 0.000014; specific heat, 0.095; latent heat of fusion, 50.6 B.T.U. per pound; heat transmitted, per second, through metal 1 inch thick, per square inch of surface, for a temperature difference of 1 degree F., 0.0017 B.T.U.; heat conductivity compared with silver (silver = 100), 36; electric conductivity (silver = 100), 29.6; ultimate tensile strength of cast zinc, about 5000 pounds per square inch (but may vary from 4000 to 14,000 pounds per square inch); ultimate strength in compression, about 20,000 pounds per square inch; modulus of elasticity, 13,000,000. Commercial zinc is generally known as *spelter*.

Zinc Ores. — Zinc does not occur free in nature, although it is very common in various combinations. The four important ores are zinc oxide, zinc sulphide, or blende, zinc silicate, and zinc sulphate. The greater part of zinc found in nature is in the form of zinc sulphide, but, as this is infusible, it must be oxidized, when zinc oxide, zinc sulphide, and sulphur dioxide are formed. By heating zinc silicate to a high temperature, it is reduced by carbon, and metallic zinc, carbon monoxide, and silica slag are formed. All zinc ores, except the oxides, are first converted into zinc oxide, which is then distilled with carbon, and the distillate of metallic zinc is condensed. This metallic zinc is refined in a furnace.

Uses for Zinc. — One of the most important uses of zinc is as a coating for iron. In the galvanizing process, sheets of iron are immersed in a bath of molten metal and then removed; a coating of zinc remains on the iron which is thereby protected from atmospheric corrosion. Zinc may also be electrolytically deposited upon iron. Electrolytically-deposited zinc is of a dull color and its appearance is not as satisfactory as that obtained by

dipping iron sheets into molten zinc. It has been shown, however, that electrolytically-deposited zinc protects the iron better for a given thickness of deposit than does a coating made from molten zinc. Zinc is also used in many alloys, the most common of which is *brass*.

ZINC-ALUMINUM ALLOYS. See Aluminum Alloys.

ZINC CASTINGS. Pure zinc castings are used for certain special purposes. For example, the dies or blocks on which hats are made are usually cast from zinc. The patterns for pure zinc castings are usually made from plaster-of-paris, and the molding is similar to that of other metals. Another use for cast zinc is for making monuments and statues, the metal then being marketed under the name of "white bronze." For many purposes of inside decoration, a metal casting that can be easily bronzed or otherwise finished is desirable. Zinc, when alloyed with some copper, is frequently used, although, as a general rule, brass or bronze castings are preferable. Brass and bronze, however, must be cast at a temperature of from 1700 to 1900 degrees F., according to the composition of the alloy, whereas zinc, alloyed with a small amount of copper, can be cast at a temperature of from about 800 to 900 degrees F., which is an important consideration, especially when plaster molds are used. If the zinc castings are large and are to be used for monuments or statues, they are generally cast in sections in sand, and the sections are subsequently brazed together.

ZINC CEMENT. Zinc cement is a cement composed of zinc oxide which is made into a paste by means of a solution of zinc chloride. The peculiar quality of zinc cement is that it hardens quickly, and it may, therefore, be used for various purposes where this quality is of value. A cheaper form of zinc cement may be made from commercial zinc-white, mixed with an equal weight of fine sand, and made into a paste by means of a solution of zinc chloride. This cement is frequently used for filling cracks in metals, and for cementing glass, porcelain, etc.

ZINC CHROMATE. Zinc chromate is a yellow pigment made from zinc salts and potassium dichromate. It is fairly soluble in water and generally contains other chromates and zinc oxide, with some impurities. It has a specific gravity of 3.5, and grinds to a paste in 25 per cent of oil. Considerable drier is required as it is a slow drying material, but it has proved to be one of the most inhibitive of all pigments in use and is valuable in even small amounts in protective paints. Its rather high price is its only disadvantage.

ZINC-DUST. Zinc-dust, also known as *zinc powder*, is metallic zinc in the form of a fine powder. It may be obtained in two ways: 1. By grinding zinc, heated to a temperature of from 400 to 500 degrees F., in an iron mortar. 2. By rapid cooling of zinc vapor in the reduction of the metal from

its ores. In this case, the zinc-dust is more or less mixed with zinc oxide. Zinc-dust is used as a deoxidizing agent in the textile industries, and also in making protective paints for iron work.

ZINC GAGE. This gage applies to sheet zinc only. For zinc wire the American or Brown & Sharpe wire gage is employed. Tables of these gages are in MACHINERY'S HANDBOOK.

ZINC IRON. Zinc iron is an alloy of iron and zinc, obtained by dissolving the iron in molten zinc at a high temperature. This alloy is used for introducing iron into copper-zinc and copper-tin alloys.

ZINCOID POLE. The zincoid pole of a voltaic cell is the negative pole, also known as the *zincode*, and consists of a zinc plate or rod. The positive pole is formed by a copper plate. The zincoid pole may also be defined as the anode of an electrolytic cell. An electrode is said to be *zincopolar* if it has the same polarity as the zinc plate in a galvanic cell.

ZISIUM. Zisium is a trade name for an alloy of aluminum, zinc, tin, and copper, aluminum being the chief constituent. Traces of antimony and bismuth are also present. The alloy is used in the making of scientific instruments. *Ziskon* is another trade name used for an alloy of aluminum and zinc, containing about 75 per cent of aluminum and 25 per cent of zinc. The alloy is also used in the making of scientific instruments.